

VEGETABLE PRODUCTION RECOMMENDATIONS

2010-2011

Publication 363



Discard old editions of this publication. Each year the appropriate sub-committee of the Ontario Pest Management Research and Services Committee reviews the pesticides listed in this publication. To the best knowledge of the committee, at the time of printing, the pesticide products listed in this publication were:

- federally registered
- classified by the Ministry of the Environment (MOE)

The information in this publication is general information only. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) does not offer any warranty or guarantee, nor does it assume any liability for any crop loss, animal loss, health, safety or environmental hazard caused by the use of a pesticide mentioned in this publication.

This publication lists a number of brand names of pesticides. It is neither an endorsement of the product nor a suggestion that similar products are ineffective.

The Pesticide Label

Consult each product label before you use a pesticide. The label provides specific information on how to use the product safely, hazards, restrictions on use, compatibility with other products, the effect of environmental conditions, etc.

The pesticide product label is a legal document. It is against the law to use the product in any other way.

Federal Registration of Pesticide Products

The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticide products for use in Canada based on following an evaluation of scientific data to ensure that the product has merit and value; and the human health and environmental risks associated with its proposed use are acceptable.

1. Full Registration

Pesticide registrations are normally granted for a period of five years, subject to renewal.

2. Conditional Registration

Conditional registration may be granted for a specified, limited time period, where the registrant agrees to produce additional scientific or technical information, or the pesticide is used for emergency control of a serious pest outbreak.

Maximum Residue Limits

The PMRA has established maximum residue limits (MRLs) for pesticides. Processors or retailers may demand more restrictive limits. Growers should seek advice of their intended market to determine if more restrictive limitations apply. Keep accurate and up-to-date records on pesticide use in each crop.

Supplemental Labels

You **MUST** obtain a supplemental label and follow all the label directions when PMRA approves new uses for a registered pesticide that do not appear on the current label.

Examples of when you must use a supplemental label include:

- **Emergency Use Registration**
- **Minor Use Label Expansion**

You can obtain a copy of a supplemental label from the pesticide manufacturer or pesticide vendor, the grower association that sponsored the emergency registration or minor use, from OMAFRA or PMRA's Pest Management Information Service.

For more information on the federal registration status check the PMRA website at www.pmr-arla.gc.ca or call 1-800-267-6315.

Regulation of Pesticides in Ontario

The MOE is responsible for regulating pesticide sale, use, transportation, storage and disposal in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 63/09.

All Pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 63/09, which are available on the e-laws website at www.e-laws.gov.on.ca or call ServiceOntario Publications Toll-Free number: 1-800-668-9938 or 416-326-5300.

Classification of Pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the MOE, the classification of pesticide products before they can be sold or used in Ontario. Once approved by the MOE, classified products are posted on the MOE website: www.ene.gov.on.ca.

Certification and Licensing

Growers and their Assistants

For information about certification for growers and training for assistants check the Ontario Pesticide Education Program website: www.opec.ca or call 1-800-652-8573.

Commercial Applicators and their Assistants

For more information about exterminator certification and licensing and technician training check the Ontario Pesticide Training & Certification website at www.ontariopesticide.com/OPTC/default.htm or call 1-888-620-9999 or 519-674-1575.

Cette publication est aussi disponible en français.

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Need technical or business information?

Contact the Agricultural Information Contact Centre at:

1-877-424-1300 or ag.info.omafra@ontario.ca

Looking for vegetable production recommendations on the Internet?

www.ontario.ca/crops

It's one-stop shopping for Factsheets, articles and photos regarding the production and management of Ontario's vegetable crops.

Acknowledgements

The recommendations in this publication have been prepared in consultation with:

- Ontario Pest Management Research & Services Committee
- Ontario Horticultural Research & Services Committee
- Ontario Soil Management Research & Services Committee
- Ontario Weed Committee

and personnel of:

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- University of Guelph
- University of Guelph – Ridgetown Campus
- Ontario Ministry of Environment
- Agriculture and Agri-Food Canada

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1. Vegetable Crop Fertility

For a complete guide to soil fertility, see OMAFRA Publication 611, *Soil Fertility Handbook*.

Soil fertility is an important component in the production of high yielding, top-quality vegetable crops. However, soil fertility is only one part of a crop management program. The effectiveness of a soil fertility program will depend on careful soil and water management, as well as crop protection. Developing a good, sound soil fertility program begins with assessing the crop and the soil's nutrient needs.

Assessing Nutrient Needs

There are three ways to assess soil and crop fertility:

- visual deficiency symptoms
- soil testing
- plant analysis

Visual Deficiency Symptoms

Leaf symptoms are helpful for evaluating some nutrient deficiencies. Unfortunately, by the time deficiency symptoms are visible, yield losses may have already occurred. Visual deficiency symptoms may also be easily confused with other production problems, such as herbicide injury, leaf and root diseases, nematodes, insect damage, compaction or air pollution. Cases of suspected visual deficiencies can often be confirmed with leaf or plant analysis. Visual leaf deficiency symptoms are described in the individual nutrient sections in Chapter 9, *Crop Management Recommendations*, starting on page 67.

Soil Testing

Soil testing is the most accurate tool available to determine nutrient requirements for a crop. The OMAFRA-accredited soil-testing program provides quality assurance of the soil testing process. OMAFRA-accredited laboratories participate in the North American Proficiency Testing Program. The analytical methods used by OMAFRA-accredited laboratories were chosen to provide accurate results on the range of soils found in Ontario. Table 1-1, *OMAFRA-Accredited Soil Tests*, this page, lists the accredited soil tests.

Table 1-1. OMAFRA-Accredited Soil Tests

See Appendix C, *Accredited Soil-Testing Laboratories in Ontario*, on page 235, for a list of accredited labs in Ontario.

Materials	What Is Analyzed
Soils for field-grown crops, commercial turf, etc.	Plant-available phosphorus (sodium bicarbonate extractable) potassium, magnesium (ammonium acetate extractable) manganese and zinc (index of soil pH and extractable element) pH lime requirement (SMP buffer pH)

A test for soil organic matter can be useful but is not an accredited test. OMAFRA-accredited soil tests are not available for boron, copper, iron or molybdenum. Tissue analysis of these micronutrients is a better indicator of the crop nutrient status. See *Plant Tissue Analysis*, on page 3.

When to Sample

Sample each field once every 2 or 3 years. Potassium levels can change quickly on sandy soils where large amounts of nutrients are removed by the crop, especially if there is limited crop residue left on the soil surface. Examples of heavy potassium feeders include alfalfa hay, silage corn, potatoes, sugarbeets and tomatoes. In these cropping systems, consider sampling more frequently.

Sample soils in the fall or in the summer. Make it a habit to sample at the same time each year for more consistent sample results. The period following wheat harvest is often a convenient time in the crop rotation to take samples. Late-summer or fall sampling is ideal for fields to be seeded in the spring. Regardless of when the sample is taken, allow time for mailing the samples and receiving the report.

Taking a Soil Sample

The accuracy of the soil test and the resulting recommendations depend on properly taking, preparing and submitting the soil sample. The following items are required for soil sampling:

- a soil probe or a shovel
- a clean plastic pail. Do not use galvanized metal pails; these will contaminate the sample for micronutrient analysis, particularly zinc.

- sample bags and boxes, usually available from the soil laboratory
- a pen or marker

Sample each field separately. Divide large fields and fields with considerable variation into smaller sections. Each field section should have relatively the same soil texture, topography, organic matter and cropping history.

Micronutrient deficiencies frequently occur in small patches in fields. Take a separate sample for any problem areas of the field. When sampling a problem area, be sure to take a comparison sample from an adjacent good area.

For a basic test, use a sampling tube or shovel to remove a core of soil to a depth of 15 cm. Nitrate-nitrogen samples are taken to a depth of 30 cm. Take at least 20 soil cores for fields up to 5 ha (12 acres) in size. Take proportionately more cores for fields larger than 5 ha. The more cores taken, the more reliable the measure of the fertility in the field. One sample should not represent more than 10 ha (25 acres). For more information on nitrate-nitrogen samples, see *Pre-Side-Dress Nitrogen Test*, on page 8.

Travel the area sampled in a zigzag pattern to provide a good variety of sampling sites. Avoid sampling recent fertilizer bands, dead furrows, areas adjacent to gravel roads or areas where lime, manure, compost or crop residues have been piled.

Break the lumps. Mix the soil well before sending a sample for testing. Approximately 2 mL of each sample are used for the analysis so a well-mixed sample will provide greater accuracy. Fill a clean plastic bag with approximately 500 g of soil and place it in the box. Be sure to clearly mark the sample with all the necessary information (i.e., sample number, farm name, date, etc.).

Interpreting the Results

The OMAFRA-accredited soil-testing program provides recommendations for nitrogen, phosphate, potash, magnesium, zinc and manganese fertilizer. It also gives recommendations for the amount and type of lime to be applied, if required. OMAFRA-recommended fertilizer rates are provided in the commodity sections of this publication, starting on page 67, and in Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, and Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15. These recommendations can produce the highest economic yields when accompanied by good or above-average crop production management.

Table 1–2. Soil Test Nutrient Ratings

Response Category	Probability of Profitable Response to Applied Nutrients
High Response (HR)	high (most of the cases)
Medium Response (MR)	medium (about half the cases)
Low Response (LR)	low (few of the cases)
Rare Response (RR)	rare (very few of the cases)
No or Negative Response (NR)	not profitable to apply nutrients

In a basic soil test, each nutrient is given a numerical value, a letter rating and a fertilizer recommendation for the crop specified on the soil test submission form (usually in lb/acre or kg/ha). Soil test results for phosphorus, potassium and magnesium are reported in units of milligrams per litre of soil (mg/L), which is approximately equal to parts per million (ppm). Manganese and zinc are reported as indexes that account for both the amount of nutrient extracted from the soil and the soil pH.

The Ontario soil test nutrient ratings reflect the likelihood of having a large enough response to applied fertilizer, in the year of application, to pay for the fertilizer and allow additional profit for the grower. The rating system is explained in Table 1–2, *Soil Test Nutrient Ratings*, this page. A different rating system was used on soil tests taken prior to 2008. When using an older soil test, select a fertilizer rate based on the numerical (ppm or mg/L) soil test value reported on the soil test.

A soil test recommendation is affected by manure application, plowing down of legume sod and the type of crop to be fertilized. This information is essential for a valid fertilizer recommendation. Recommended fertilizer rates, especially for nitrogen and phosphorus should be adjusted if manure and cover crops are used.

There are several methods used in developing fertilizer recommendations from soil test results.

OMAFRA-Accredited Recommendations

The OMAFRA-accredited program uses field trials to determine the optimal rate of application for each nutrient. This amount is most likely to maximize profit in the year of application. Applying nutrients at the OMAFRA-recommended rate will maintain or gradually increase soil fertility. As a nutrient's soil test value increases, the economic return per unit of fertilizer decreases. The soil test ratings of low response (LR), rare response (RR) or no response (NR) indicate that an economic response to adding more of that nutrient is unlikely. Adding nutrients to soils with an NR rating may reduce crop yields or quality by interfering with the uptake of other nutrients.

Soil Tests From Other Laboratories

Each year, a number of farmers ask how to interpret results from laboratories that are not accredited. Provided the other laboratory uses the identical test used by the OMAFRA-accredited service and expresses results in the same units, the OMAFRA fertilizer requirements for phosphate and potash can be determined. However, there is no assurance of the accuracy of the analysis.

Only OMAFRA-accredited soil tests can be relied on to provide accurate fertilizer recommendations. Be certain that the service you are using is accredited. To be accredited, a laboratory must use OMAFRA-approved testing procedures, must demonstrate acceptable analytical precision and accuracy and must provide the OMAFRA fertilizer recommendations. Soil tests on farms that must complete a nutrient management plan must be carried out at OMAFRA-accredited labs.

Crop Removal Recommendations

The crop removal system selects fertilizer rates to replace the nutrients removed in the harvested crop portion. This system does not account for naturally occurring levels of nutrients supplied by the soil. As a result, the rates recommended for phosphorus and potassium are often uneconomical. On soils with a rating of low response (LR), rare response (RR) or no response (NR), the increase in yield may not pay for the additional fertilizer recommended through crop removal calculations. Alternatively, many vegetable crops have comparatively low nutrient removal values. In these instances, the recommended fertilizer rates may be lower than the amount needed to support crop growth and quality. On soils with a high response rating, crop removal may result in an insufficient fertilizer application. Phosphorus and potassium fertilizer requirements are not closely related to crop removal of phosphorus and potassium.

Build-up and Maintenance Recommendations

Build-up and maintenance recommendations aim to meet the crop's annual nutrient requirement and to improve the soil-test value. Additional fertilizer is recommended to maintain high soil test levels despite the low probability of an economical response. High levels of some nutrients may interfere with the uptake of others and cause yield reductions. There is no economic advantage to maintaining soil test levels in the rare response (RR) or no response (NR) range. Most crops can be grown on these soils for several years before fertilizer is required.

Base Saturation Ratio Recommendations

Some soil reports use base saturation ratios to develop recommendations for potassium, calcium and magnesium. This system is designed to result in "ideal" proportions of each nutrient in relation to the others. The ratios of these three nutrients are used as indicators of their availability. Crops can grow at a wide range of potassium-calcium-magnesium ratios. Many Ontario soils are naturally high in calcium and magnesium. As a result, the rates of potassium recommended in this system are often high and uneconomical. Striving to meet an exact ratio has little, if any, effect on crop yield.

Plant Tissue Analysis

Plant tissue analysis measures the nutrient content within the plant tissue. This can be a useful addition to soil testing. Plant analysis results are compared against established normal ranges for the crop, indicating whether a specific nutrient is excessive, sufficient or deficient. For some nutrients, this can indicate whether the soil nutrient supply is adequate for optimum growth. If soil levels are known to be adequate, plant analysis may indicate other problems that are reducing nutrient uptake.

When the nutrients are within the sufficiency range, increasing the nutrient concentration in the leaf is unlikely to result in increased crop growth. The objective of a good fertility program is to maintain tissue concentrations at the lower end of the range. Attempting to bring the nutrient analysis up to the higher end could possibly result in over-fertilization and may not be cost effective.

Plant analysis is particularly useful for evaluating phosphorus, potassium, magnesium and manganese. It is also very useful in assessing the status of boron, copper, iron or molybdenum, as reliable soil tests are not available for these nutrients. Plant analysis has not been very reliable for evaluating nitrogen and zinc.

Plant analysis has limitations. Expert help in interpreting the results is often needed. Plant analysis does not usually indicate the cause of a deficiency or the amount of fertilizer required for correcting it. The timing of plant analysis on many vegetable crops is difficult. Rapid growth and a relatively short growing season mean that yield loss may have already occurred by the time sample results are available. However, it is a valuable tool for diagnosing nutrient-related problem areas in the field for future corrective measures. Plant analysis is most useful when it is combined with visual inspection of the crop and soil conditions, knowledge of past management in the field and a current soil test to provide information about soil nutrient levels and soil pH.

There is no formal accreditation process for plant tissue analysis. However, accredited labs that perform plant analysis are monitored and provide quality analysis and interpretation of plant tissue samples.

Sampling

Time of sampling has a major effect on the results of plant analysis. Nutrient levels within a plant vary considerably with age and physiological stage. Recommended sampling stages have been developed for most vegetable crops. Results are difficult to interpret if samples are taken at times other than those recommended. For most crops, sample the most recently mature leaf from each plant. Very old and very young leaves often provide misleading results. Sample any plant suspected of being nutrient deficient as soon as a problem appears.

To diagnose a specific crop problem, take tissue samples from the problem area rather than from the entire field. Collect and submit a separate sample from an adjacent, non-affected part of the field for comparison purposes. Take leaves from at least 20 plants distributed throughout the area being sampled. Each sample should consist of at least 100 g of fresh material.

Collect tissue samples into labelled paper bags. Plant tissues will rot if they are stored in plastic bags. Avoid contaminating the sample with soil, dust or metal. Even a small amount of soil will cause the results to be invalid, especially for micronutrients. Wash any soil from the leaves prior to shipping them to the lab.

Collect and submit a soil sample from both affected and non-affected areas to accompany the tissue sample. This soil sample can help address whether the nutrient deficiency is a result of limited soil availability or due to other factors.

Sample Preparation

Deliver fresh plant samples directly to the laboratory. If this is not possible, dry them at a low temperature (no greater than 65°C) to prevent spoilage.

Plant analyses may be obtained from several laboratories in Ontario. See Appendix C, *Accredited Soil-Testing Laboratories in Ontario*, on page 235. Tissue analysis is not an OMAFRA-accredited test.

Table 1-3. Soil pH at Which Lime Is Recommended for Ontario Field-Grown Crops

Crop	Soil pH Below Which Lime Is Recommended	Target Soil pH ¹
Coarse- and Medium-Textured Mineral Soils (sands, sandy loams, loams and silt loams)		
All crops not listed below	6.1	6.5
Corn, soybeans, winter rye, grass hay and pasture, turf, tobacco, established tree fruits and grapes	5.6	6.0
Potatoes	5.1	5.5
Fine Textured Mineral Soils (clay and clay loams)		
Alfalfa, brassica crops, rutabaga	6.1	6.5
All crops not listed below or above	5.6	6.0
Corn, rye, grass hay, and pasture, tobacco, established tree fruits and grapes, potatoes	5.1	5.5
Blueberry, cranberry, rhododendron, azalea	No lime recommended	
Organic Soils (peats and mucks)		
All field and vegetable crops	5.1	5.5
Where a crop is grown in rotation with other crops requiring a high pH, lime the soil to the higher pH. Crops with significantly different pH requirements (e.g., potatoes and brassica crops) may not be a suitable rotation.		

¹ Where a crop is grown in rotation with other crops requiring a high pH, lime the soil to the higher pH. Crops with significantly different pH requirements (e.g., potatoes and brassica crops) may not be a suitable rotation.

Soil pH and Liming

Two of the most important values reported on the soil test report are the soil pH and the buffer pH. These are important, because pH affects crop growth, nutrient availability and some soil-borne diseases. To correct soil acidity, broadcast ground limestone and work it into the soil at rates determined by a soil test. Table 1-3, *Soil pH at Which Lime Is Recommended for Ontario Field-Grown Crops*, this page, shows the soil pH values below which lime is recommended and the "target" soil pH to which soils should be limed for different crops. In Ontario, most crops grow quite well at pH values higher than the target pH.

What is pH?

pH is a measure of the level of acidity or alkalinity of the soil. The pH scale ranges from 0 to 14 and reflects the hydrogen ion concentration in the soil. A pH value of 7.0 is neutral. Values below 7.0 are acidic. Those above 7.0 are alkaline or basic. On mineral soils, most vegetable crops grow well in a soil pH range from 6.0 to 7.5. A range of 5.0 to 6.0 is acceptable on muck soils. Maintaining soil within the appropriate pH range is important. Some crop nutrients become less available at a soil pH outside the ideal range, while others become more available. Either situation could result in the potential for nutrient deficiencies or toxicities.

Table 1-4. Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pHGround limestone required — tonne/ha
(based on an Agricultural Index of 75)

Buffer pH	Target soil pH = 7.0 ¹	Target soil pH = 6.5 ²	Target soil pH = 6.0 ³	Target soil pH = 5.5 ⁴
7.0	2	2	1	1
6.9	3	2	1	1
6.8	3	2	1	1
6.7	4	2	2	1
6.6	5	3	2	1
6.5	6	3	2	1
6.4	7	4	3	2
6.3	8	5	3	2
6.2	10	6	4	2
6.1	11	7	5	2
6.0	13	9	6	3
5.9	14	10	7	4
5.8	16	12	8	4
5.7	18	13	9	5
5.6	20	15	11	6
5.5	20	17	12	8
5.4	20	19	14	9
5.3	20	20	15	10
5.2	20	20	17	11
5.1	20	20	19	13
5.0	20	20	20	15
4.9	20	20	20	16
4.8	20	20	20	18
4.7	20	20	20	20
4.6	20	20	20	20

¹ Liming to pH 7.0 is recommended only for club-root control on brassica crops.² Add lime if soil pH is below 6.1.³ Add lime if soil pH is below 5.6.⁴ Add lime if soil pH is below 5.1.

Buffer pH

The soil pH measures the amount of acidity in the soil solution, indicating whether liming is necessary for crop production. It does not measure the amount of reserve acidity held on the clay and organic matter particles in the soil, which will dictate how much lime is needed. Different amounts of reserve acidity will mean that two soils at the same pH value will need different amounts of lime to raise the pH to the desired level. The reserve acidity is measured in a separate test: the buffer pH. The greater the amount of reserve acidity, the lower the buffer pH and the more lime is required to raise the pH.

Table 1-5. Lime Requirement Equations Based on Soil Buffer pH

pH to which soil is limed	Equation (based on lime with an agricultural index of 75)
7.0	Lime (t/ha) = 334.5 - 94.79 pHB + 6.19 pH ²
6.5	Lime (t/ha) = 291.6 - 80.99 pHB + 5.64 pH ²
6.0	Lime (t/ha) = 255.4 - 73.15 pHB + 5.26 pH ²
5.5	Lime (t/ha) = 37.7 - 5.75 pHB

pHB = pH in Shoemaker, McLean and Pratt (SMP) buffer

For soils needing lime (based on soil pH), Table 1-4, *Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH*, this page, may be used to determine the amount of lime required to reach the target soil pH values required for different crops.

The lime requirements in Table 1-4 are based on the equations presented in Table 1-5, *Lime Requirement Equations Based on Soil Buffer pH*, this page, with values rounded to the nearest t/ha. A minimum recommendation was set at 1 t/ha and a maximum at 20 t/ha. More exact requirements may be calculated from the equations presented in Table 1-5.

Raising the Soil pH With Limestone

Soil pH is raised by applying either calcitic or dolomitic limestone. The carbonate in the limestone neutralizes the soil acidity. Calcitic limestone consists largely of calcium carbonate. Dolomitic limestone is a mixture of both calcium and magnesium carbonates.

Use dolomitic limestone on soils with a magnesium soil test of 100 ppm or less. It is an excellent and inexpensive source of magnesium for acid soils. Use either calcitic or dolomitic limestone on soils with magnesium test results greater than 100 ppm. Limestone's effectiveness in adjusting soil pH depends on its neutralizing value and its fineness rating.

Neutralizing Value

Neutralizing value is the amount of acid a given quantity of limestone will neutralize when it is totally dissolved. It is expressed as a percentage of the neutralizing value of pure calcium carbonate. A limestone that will neutralize 90% as much acid as pure calcium carbonate is said to have a neutralizing value of 90. In general, the higher the calcium and magnesium content of a limestone, the higher its neutralizing value.

Table 1–6. Example Calculation of the Fineness Rating of Limestone

Particle Size	% of sample		Effectiveness Factor		
Coarser than No. 10 sieve ¹	10	x	0.0	=	0
No. 10 sieve to No. 60 sieve	40	x	0.4	=	16
Passing through No. 60 sieve ²	50	x	1.0	=	50
Fineness Rating				=	66

¹ A No. 10 sieve has wires spaced 2.0 mm apart.² A No. 60 sieve has wires spaced 0.25 mm apart.

Fineness Rating

Fineness rating, or particle size, also affects the value of limestone. The higher the fineness rating, the more rapidly the limestone reacts with the soil pH. A fineness rating calculation for ground limestone is illustrated in Table 1–6, *Example Calculation of the Fineness Rating of Limestone*, this page.

The Agricultural Index

The Agricultural Index combines the neutralizing value and the fineness rating of a limestone. It provides a way of comparing different limestone sources. For example, a limestone with a high agricultural index is worth proportionately more than limestone with a low index because it may be applied at a lower rate. A limestone's agricultural index is determined by the following formula:

$$\text{The Agricultural Index} = \frac{\text{neutralizing value} \times \text{fineness rating}}{100}$$

Recommendations from the OMAFRA-accredited soil tests are based on limestone with an Agricultural Index of 75. When using a lime source with a different Agricultural Index, a specific rate of application may be calculated using the following equation:

$$\text{Limestone application rate from soil test} \times \frac{75}{\text{Agricultural Index of your limestone}} = \text{Rate of application of your limestone}$$

For example, assume the soil test recommends 9 t/ha of limestone. If the limestone source has an Agricultural Index of 90, the application rate should be 7.5 t/ha ($9 \times 75/90 = 7.5$ t/ha).

The Agricultural Index does not provide information about magnesium content.

Effect of Tillage Depth

Lime recommendations presented in Table 1–4, *Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH*, previous page, should raise the pH of

the top 15 cm of a soil to the listed target pH. If the soil is plowed to a lesser or greater depth than 15 cm, proportionately more or less lime is required to reach the same target pH. Where shallow tillage depths are used, more frequent applications of lower rates are recommended.

Lowering Soil pH

On soils with pH values below 6.5, it is possible to lower the pH and make the soil more acidic. This can be done by adding sulphur or ammonium sulphate. This may be desirable for some crops, such as potatoes, for scab control. However, it may not be suitable for other crops in the rotation. It is not possible to adjust pH up and down from year to year. pH recommendations should be developed to meet the needs of all the crops in the rotation. If the soil pH is above 6.5, it is not practical to lower the soil pH because very large amounts of sulphur or ammonium sulphate will be required.

Starter Fertilizers for Vegetable Crops

Research has shown that phosphorus availability and root growth are reduced in cool soils. As a result, many early-season vegetable crops benefit greatly from having small amounts of phosphorus applied to the rooting zone at seeding or transplanting. For crops planted later in the season, under more favourable soil conditions, there is little benefit to adding extra phosphorus at planting.

Although the most important starter nutrient is phosphorus, small amounts of nitrogen are often included to improve early vigour. Ammonium-nitrogen enhances the absorption of phosphorus by the plant.

On low potassium soils, there may be a response to potassium in the starter fertilizer, but in most cases potassium will not provide a benefit.

The most common method of applying starter nutrients to transplanted vegetables is through water soluble or liquid fertilizers applied with the planter water. For some seeded vegetables, starter fertilizers may be banded 5 cm below and 5 cm to the side of the seed. Seed-placed fertilizers are generally not recommended for use with vegetable crops. See the individual crops sections in Chapter 9, starting on page 67, for specific recommendations for safe rates of starter fertilizers.

Which to Choose: Soil or Foliar Fertilizers?

Both soil and foliar fertilizers have a role to play in vegetable crop production. The major nutrients (nitrogen, phosphorus, potassium, calcium and magnesium) are required in relatively high amounts for crop growth. Foliar uptake occurs through the leaf's cuticle and the stomata. The amount of nutrients that can enter the plant through these means is quite limited, and increasing the application rates may lead to crop injury. As a result, soil application is almost always the most efficient and economical method of getting the major nutrients into the plant.

Micronutrients, which are required by the crop in much lower quantities, can often be efficiently delivered through foliar applications, especially when soil conditions impact the nutrient's availability. Depending on the micronutrient and the timing at which the deficiency is identified, either soil-applied or foliar fertilizers may be recommended. Specific recommendations regarding application methods are discussed in the individual commodity sections, starting on page 67.

Foliar-applied nutrient uptake can be improved through the timing of the application and the use of surfactants. Younger leaves generally have a less well-developed cuticle and are able to take in more of the nutrient. Early-morning applications may favour foliar uptake. Avoid applying foliar nutrients during the heat of the day when leaves will dry quickly; this will reduce the effectiveness of uptake. Ensure good leaf coverage, particularly on the lower leaf surfaces.

Avoid Fertilizer Burn

Many nitrogen and potash fertilizer materials contain high amounts of salts. If a germinating seedling or young transplant comes into contact with a concentrated fertilizer band, the roots may become seriously damaged. For this reason, ensure that the correct fertilizer, the appropriate rate and the right placement are selected for each application.

Urea has a relatively high salt index. It is not suitable for use in starter fertilizers or banded applications.

Ensure that starter or transplant fertilizers contain only as much nitrogen as necessary to get the crop started. Fertilizers containing more than half as much nitrogen as phosphate frequently contain urea and may cause crop damage. Under dry soil conditions, the amount of nitrogen in the starter should be reduced or eliminated.

In general:

- Fertilizers of the same grade may vary in salt levels depending on the raw material used to formulate them.
- Nitrogen and potassium salts are more injurious than phosphorus salts.
- Fertilizers that contain micronutrients (boron, copper, iron, manganese, zinc) are more phytotoxic than the same grades of fertilizer without micronutrients. The use of micronutrients in the starter fertilizer is generally not recommended.

Nitrogen

Nitrogen is an important element for the growth and development of all crop plants. As a component of chlorophyll, it plays a vital role in photosynthesis. Nitrogen is also one of the building blocks for the formation of amino acids, protein and enzymes.

Nitrogen is naturally present in all soils. Soil microbes feed on crop residues and soil organic matter, releasing nitrogen into the soil. As soil organic matter levels increase, so do the levels of naturally available nitrogen. As a result, good soil management practices enhance a soil's natural fertility levels. Legumes, such as alfalfa, build soil fertility by capturing atmospheric nitrogen and releasing it into the soil as they decompose.

Visual Deficiency Symptoms

Nitrogen deficiencies usually first appear on older leaves. These leaves will turn light green or yellow as nitrogen is relocated from older, less productive leaves to the newest growth. Cool weather in early spring often causes plants to develop a temporary nitrogen deficiency. This is usually due to poor growing conditions and slow root development, not necessarily a lack of nitrogen in the soil.

Nitrogen and the Environment

Soil nitrogen is in a constant state of change. Processes such as leaching and denitrification result in the loss of nitrogen from the soil. Denitrification occurs when the soil is waterlogged and anaerobic microbes convert nitrate and ammonia into nitrous oxide gas. These gasses can contribute to air pollution and poor air quality and are approximately 100 times more potent as a greenhouse gas than carbon dioxide.

The nitrate form of nitrogen, while being readily available to plants, is also very water soluble. As a result, nitrates leach through the soil profile with the

soil water, causing the potential for groundwater and surface water pollution.

When the amount of nitrogen supplied to the crop does not exceed the crop's growth requirements, the risk of losses to the environment is greatly reduced. The potential for nitrogen loss is highest during the late fall and early spring. By applying nitrogen according to the crop's needs, the amount of residual nitrogen left over at the end of the season is minimal, leaving little potential for losses.

It is important to account for fertilizer, manure and other sources of nitrogen when assessing a crop's nutrient requirements. Other management practices to reduce the risk of nitrate losses include:

- growing cover crops
- timing nitrogen applications close to crop nitrogen uptake
- reducing total nitrogen applications

For more information on the nitrogen cycle and its role in the environment, see OMAFRA Publication 611, *Soil Fertility Handbook*.

Nitrogen Recommendations

Nitrogen fertilizer recommendations for vegetable crops are developed from field research trials conducted in Ontario. Recommended rates are presented under *Fertility* in the individual commodity sections in Chapter 9, *Crop Management Recommendations*, starting on page 67.

Decrease nitrogen fertilizer rates if manure is applied or if the previous crop contained legumes such as alfalfa or red clover.

Pre-Side-Dress Nitrogen Test

The pre-side-dress nitrogen test (PSNT) is a tool that can help assess the level of plant-available nitrate-nitrogen present in the soil during the growing season. Developed for use in field corn production, this test can aid in determining additional fertilizer requirements for vegetable crops.

To take a soil sample:

- Take nitrate-nitrogen soil samples to a soil depth of 30 cm.
- Sample approximately 1 week prior to the intended application. Side-dressing normally coincides with the start of a crop's rapid growth phase.

- Collect soil cores from representative areas of the field. Sample problem areas separately.
- Thoroughly mix the soil from approximately 20–25 cores.
- Package approximately 500 g of soil in a clean plastic bag.
- Chill or freeze the sample immediately. If the sample cannot be delivered to the lab in a chilled or frozen condition, allow it to air dry on a clean plastic sheet for 1–2 days prior to shipping. Microbial activity can drastically change the nitrate-nitrogen content, if the samples are not handled properly.

The PSNT results are expressed in parts per million (ppm) of nitrate-nitrogen. To convert this number into kg/ha, multiply by 3.96. For example a nitrate-nitrogen test reading 15 ppm represents 59.4 kg/ha. Research in field corn has shown that there will be minimal yield response to additional fertilizer nitrogen if the PSNT values are greater than 30 ppm.

The PSNT is a tool that was developed for use in field corn production and has not been calibrated for horticultural crops. It can give a relative indication of the amount of nitrate-nitrogen in soil at a point in time. If PSNT values are quite high, it may be possible to reduce the side-dress nitrogen fertilizer rate, however nitrate-nitrogen testing should not replace current OMAFRA fertility recommendations or grower experience.

Sources of Nitrogen

Synthetic Fertilizer

The most common sources of fertilizer nitrogen are listed in Table 1–7, *Fertilizer Materials: Primary Nutrients*, opposite page. Generally speaking, no one source of nitrogen is superior to the others. Cost, crop management and ease of application will largely determine the selection of one source over another.

Short-season crops, such as lettuce and leafy greens, may prove the exception to this rule. If the cropping season is less than 4–6 weeks, consider selecting a more rapidly available nitrogen source, such as calcium nitrate, calcium ammonium nitrate or ammonium nitrate.

With some early-planted vegetables, the use of nitrogen sources such as urea may actually help prevent leaching losses during the early part of the growing season when soil temperatures are low. Under cool soil conditions, it takes 3–6 weeks for the urea to convert into the plant-available ammonium and nitrate forms of nitrogen. As only nitrates are leached from the soil, urea and ammonium fertilizers are less susceptible to

**Table 1-7. Fertilizer Materials:
Primary Nutrients**

Nitrogen Materials	Form	% Nitrogen (N)
Ammonium nitrate	Dry	30–34
Urea	Dry	46
Ammonium sulfate	Dry	21
Calcium ammonium nitrate	Dry	27
Calcium nitrate	Dry	15.5
Aqua ammonia	Liquid	20
Urea ammonium nitrate (UAN)	Liquid	28
Anhydrous ammonia	Liquid ¹	82
Phosphate Materials	Form	% Phosphate (P₂O₅)
Single superphosphate	Dry	20
Triple superphosphate	Dry	44–46
Monoammonium phosphate (11-52-0)	Dry	48 to 52
Ammonium polyphosphate (10-34-0)	Liquid	34
Diammonium phosphate (18-46-0)	Dry	46
Potash Materials	Form	% Potash (K₂O)
Muriate of potash	Dry	60 to 62
Sulfate of potash	Dry	50
Sulfate of potash magnesia (11% Mg)	Dry	22
Potassium nitrate (13-0-44)	Dry	44

¹ Liquid under pressure.

losses during early spring rain events when the soils are cool. By the time the nitrogen conversion has occurred, the crop is entering its rapid growth phase. Leaching is less likely to occur when the crop is rapidly growing. Nitrogen conversions are very temperature dependent. As the soil heats up, these conversions occur much more rapidly.

Products That Modify the Release of Nitrogen

Slow-release fertilizers and nitrification inhibitors are a recent addition to the marketplace. Popular in the turf industry, “slow-release” fertilizers have been coated with sulphur or a polymer coating to control the release of the nitrogen over an extended period of time. Nitrification inhibitors are added to the fertilizer to help delay the chemical conversion of urea into the plant-available forms.

The behaviour of nitrogen in the soil is influenced by soil moisture and temperature. Depending on the weather conditions, the release of these products may not necessarily coincide with a vegetable crop's peak nitrogen demand, especially when short-season vegetables are being grown. These materials may cost significantly more than traditional fertilizer sources.

Manure and Food Safety

Fruit and vegetable crops can become contaminated in the field if they come into contact with pathogens that cause human illness. These pathogens may come from manure and manure-based composts. The lifespan of these pathogens in manure is not well known. Proper composting of manure, which results in heating to a specific temperature for a specific period of time, will reduce the level of most pathogens. For most vegetable crops, apply manure at least 120 days before harvest. For more information on food safety concerns in vegetable crops, see *On-Farm Food Safety*, on page 45.

Manure

The value of manure in vegetable crop production is often underestimated. In addition to nitrogen, phosphorus and potash, manure contains many secondary nutrients and micronutrients. Manure also contains valuable organic matter that helps build and maintain soil structure.

During the first growing season following application, 50%–60% of the nitrogen available in manure is available to the crop. The remaining organic nitrogen becomes available in small, diminishing quantities in the succeeding years. Up to 10% of the manure organic nitrogen can be available for the following year's crop. From solid manure, this is typically 8–11 kg/ha of nitrogen. Where manure is applied regularly to the same field, there may be a significant amount of residual nitrogen available for a crop.

The quantities of nutrients contained in manure vary from farm to farm. The type of livestock, ration, bedding, added liquids and storage system all affect the final nutrient analysis. Table 1-8, *Average Amounts of Available Nutrients for Different Types of Manure*, next page, lists the approximate amount of crop-available nitrogen contained in manure. A more detailed list is also available in OMAFRA's N-MAN program and OMAFRA Publication 811, *Agronomy Guide for Field Crops*. A manure analysis, available from several laboratories in Ontario, can provide a more accurate assessment of the nutrients contained in a specific source of manure. See Appendix C, *Accredited Soil-Testing Laboratories in Ontario*, on page 235, for a list of laboratories providing this service.

Table 1–8. Average Amounts of Available Nutrients for Different Types of Manure

Nutrient values based on average analysis results for over 3,000 samples¹. There are large variations between manures, so a manure analysis is your best guide to nutrient availability.

Manure	% Average Dry Matter	Available ² N Spring	Available ³ P ₂ O ₅	Available ⁴ K ₂ O
		kg/1,000 L (lb/1,000 gal)		
Liquid dairy	8.4	1.8 (18)	.77 (7.7)	2.6 (26)
Liquid hog	3.7	2.7 (27)	1.2 (12)	1.9 (19)
Liquid poultry	10.5	5.8 (58)	2.8 (28)	3.2 (32)
kg/tonne (lb/ton)				
Solid poultry	55.3	10.5 (21)	11 (22)	13.4 (26.8)
Solid dairy	25.0	1.8 (3.6)	1.5 (3.0)	5.2 (10.5)
Composted dairy	38.3	2.9 (5.8)	2.6 (5.2)	11.8 (23.8)
Solid beef	28.4	1.9 (3.8)	2.1 (4.3)	6.1 (12.2)
Sheep	33.8	2.9 (5.9)	2.6 (5.2)	8.3 (16.7)
Horse	37.4	1.3 (2.6)	1.4 (2.8)	4.6 (9.3)

¹ Data from manure analysis provided from Ontario Labs collected between 1992 and 2007.

² Nitrogen based on spring application, incorporated within 24 hr.

³ Phosphate from manure or biosolids is assumed to be 40% as available in the year of application as phosphate from commercial fertilizer (another 40% of the phosphorus is available the following year).

⁴ Potassium from manure is assumed to be 90% as available in the year of application as potassium from commercial fertilizer.

For liquid manure, an application goal of 60%–75% of the nitrogen requirements for a corn crop is reasonable. With solid manure, the release of nitrogen is much less predictable due to the high carbon content of the bedding material. Plan on budgeting for no more than 50% of the crop's nitrogen requirement from solid manure.

Manure availability for short-season vegetable crops may be less predictable. Balance manure nitrogen contributions with fertilizer nitrogen sources to ensure the crop's needs are met.

Use manure responsibly:

- Avoid spreading on frozen or snow-covered ground.
- Avoid making applications, when the potential for runoff is high.
- Tillage prior to applying liquid manure will help break up soil cracks and large pores, preventing the movement of manure into the groundwater.
- Inject or incorporate the manure to help prevent the loss of ammonia gas into the atmosphere, leaving more nitrogen in the soil, available for the crop.
- When storing or piling manure in the field, follow the management practices outlined in the OMAFRA Factsheet *Temporary Field Storage of Solid Manure or Prescribed Materials*, Order No. 05-009.

Table 1–9. Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down

Type of Sod	For All Crops, Deduct From N Requirement kg N/ha
Less than 1/3 legume	0
1/3 to 1/2 legume	55
1/2 or more legume	100
Clover cover crop	45 ¹
Soybean and field bean residue	0

¹ Applies where the stand is thick and over 40 cm high.

Legumes

Legume crops use bacteria, known as rhizobia, to capture atmospheric nitrogen. As the residue from previous legume crops decomposes, this nitrogen becomes available for subsequent crops. When vegetables follow alfalfa hay or a legume cover crop, such as red clover, decrease the rate of fertilizer nitrogen to take into consideration the amount of nitrogen supplied by the legume. The recommended adjustments can be found in Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, this page.

Biosolids

Biosolids from off-farm sources can be a useful source of nutrients and organic matter. Guidelines for their use are available from OMAFRA and the Ministry of the Environment (MOE). A Certificate of Approval for land application is required and is available from MOE. Whenever biosolids are applied, the applicator should give the landowner an analysis of the nutrients applied.

Municipal sewage biosolids from municipal sewage treatment plants may not be applied to vegetable-producing land less than 12 months before harvest.

Always consult with your processor, packer, broker or buyer before applying municipal sewage biosolids on ground intended for vegetables anywhere in the rotation.

Nitrogen Application Methods

Most nitrogen fertilizers readily dissolve in the soil water and move easily through the soil to the plant roots. For this reason, placement of nitrogen is rarely a concern. The bulk of a crop's nitrogen requirement can be broadcast prior to planting or side-dressed.

Side-Dressing

Nitrogen-use efficiency can be enhanced in many vegetable crops with a split application. A small portion of the nitrogen requirement is applied prior

to planting as a broadcast, banded or transplant water application. The remainder is applied between the rows as the crop enters its rapid growth phase. This practice helps minimize leaching and prevents fruiting vegetables, such as tomatoes, peppers and cucurbits, from developing too much vegetative growth.

Banding

Relatively low amounts of nitrogen applied at the time of planting can help promote early-season growth. By banding the fertilizer 5 cm beside and 5 cm below the seed, the fertilizer is readily available to the emerging seedling. This practice works well when used in combination with side-dress applications. When banding, select fertilizer rates with caution. A high concentration of fertilizer in the band may damage the roots of young seedlings.

See each individual commodity section in Chapter 9, starting on page 67, for specific recommendations regarding the maximum rates of nitrogen to be applied at planting.

Fertigation

Where crops are grown under fertigation, apply approximately half the crop's total nitrogen requirement prior to planting. The remainder can be injected through the fertigation system.

The objective of a fertigation system is to match nutrient applications with crop requirements and uptake. This can be achieved by applying small amounts of fertilizer regularly, as the crop develops. The weekly application rate usually increases as crop growth and demand increase. Once harvest begins, rates can be levelled off or even decreased. Recommended fertigation application rates for tomatoes, peppers and cucurbit crops appear in the commodity sections of Chapter 9, starting on page 67.

Do not use fertilizers containing calcium, phosphate or sulphate, as these elements may plug the emitters.

For more information on fertigation, see Chapter 3, *Water Management*, on page 27.

Phosphorus

Like nitrogen, phosphorus has an important role in photosynthesis and the development of enzymes and protein. It also plays an important function in cell division and in the creation and transport of sugars and starches.

Soil phosphorus levels across Ontario vary greatly. Many coarse sandy-loam soils often contain high

levels of phosphorus. Former tobacco land and soils with a history of regular manure applications often have phosphorus soil test ratings of Low Response (LR) to No Response (NR). These soils are capable of producing high-yielding vegetable crops with little or no additional phosphorus fertilizer.

Applications of additional phosphorus on low response soils may negatively impact the crop's ability to remove zinc and iron from the soil. Where phosphorus levels are high, zinc and iron deficiencies may occur.

Visual Deficiency Symptoms

Phosphorus deficiency usually develops on the older leaf tissue first. It causes these leaves to develop a purplish-red colour. This may be more noticeable on the underside of the leaves. Severe deficiencies may also cause the leaf tips to die back. Cool, wet soil conditions often trigger phosphorus deficiencies. Many vegetable crops will benefit from the use of a starter fertilizer to deliver phosphorus directly to the root zone. See *Starter Fertilizers for Vegetable Crops*, on page 6.

Phosphorus in the Environment

Phosphorus binds tightly to soil particles. When erosion moves phosphorus-rich soil into drains and water courses, it can result in poor water quality.

Avoid making additional phosphorus applications to soils testing in the Rare Response (RR) or No Response (NR) categories. If phosphorus is required to promote early-season growth, use low rates applied in a band or as a starter fertilizer.

Consider leaving a 3-m grassed buffer zone around all creeks, streams and ponds. The grass will help reduce erosion and act as a natural filter for runoff entering the watercourse.

Farms that are required to complete a nutrient management plan must establish a permanent vegetative buffer adjacent to any surface water, with a minimum width of 3 m prior to any nutrient application.

Where phosphorus soil test results are greater than 30 ppm, use the phosphorus index to determine separation distances from surface water sources. The phosphorus index uses a series of five factors, including field slope, length of slope, soil drainage class and soil texture to determine an appropriate rate and separation distance from surface water. For details on the phosphorus index, see the OMAFRA Factsheet, *Determining the Phosphorus Index for a Field*, Order No. 05-067.

Table 1-10. Phosphorus Requirements: Vegetables on Mineral Soils

Phosphorus Soil Test (mg P/L of soil) ¹	Rating ^a	Phosphate (P ₂ O ₅) Required kg/ha								
		Beans (lima & snap) Peas	Radishes	Sweet corn Asparagus (established)	Sugarbeets	Beets Carrots Lettuce Onions Parsnips Rutabagas Spinach Horseradish	Potatoes	Cucumbers Muskmelons Pumpkins Squash Tomatoes ² Watermelons	Celery Rhubarb	Broccoli ¹ Brussels sprouts ¹ Cabbages ¹ Cauliflower ¹ Eggplant ² Peppers ² Asparagus (nursery & new plantings)
0-3	HR	80	80	110	150	180	200	230	230	270
4-5		60	70	100	140	170	200	230	230	260
6-7		50	60	90	140	170	190	220	220	250
8-9		40	60	70	130	160	190	220	220	240
10-12	MR	30	50	50	130	160	180	210	220	230
13-15		20	50	20	120	150	170	190	210	220
16-20	LR	0	40	20	100	140	160	170	190	200
21-25		0	40	20	90	120	140	140	160	170
26-30	RR	0	30	20	70	100	120	110	140	140
31-40		0	30	0	50	80	90	80	110	110
41-50		0	20	0	30	50	50	50	80	80
51-60		0	0	0	0	30	30	30	50	50
61-80	NR	0	0	0	0	0	30	0	0	0
80+		0	0	0	0	0	30	0	0	0

* HR = high response MR = medium response LR = low response RR = rare response NR = no response

¹ Sodium bicarbonate (Olsen) extraction method.

² For transplanted tomatoes, peppers and eggplants, apply a starter solution, such as 1 L of 10-34-0 per 100 L of water, or 1 L of 6-24-6 per 75 L at planting.

³ For transplanted broccoli, Brussels sprouts, cabbages and cauliflower, if no insecticide is used in the planting water, apply a starter solution high in nitrogen such as 20-20-20 at 1 kg/200 L. Under high temperatures and in dry, sandy soils, use half the concentration of fertilizer.

Phosphorus Recommendations

In Ontario, phosphate fertilizer recommendations are based on OMAFRA-accredited soil tests. Soil testing is the most accurate method of determining the amount of phosphate required for healthy and productive crop growth.

Table 1-10, *Phosphorus Requirements: Vegetables on Mineral Soils*, this page, and Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, opposite page, outline crop-specific recommendations.

Only use these recommendation tables with OMAFRA-accredited sodium bicarbonate (Olsen) soil tests. Non-accredited tests may use different procedures, resulting in inappropriate recommendations if used with the OMAFRA tables. Fertilizer rates in this table are designed to produce high economic yields when accompanied by good or above-average management.

Where a soil test is not available, use the following guidelines to obtain a rough estimate of requirements from these tables:

- If the field has been fertilized regularly for a number of years, or heavily in recent years, use one of the rates recommended for the medium response (MR) soil test rating.
- If the field has received little fertilizer in the past, use one of the rates recommended for a high response (HR) soil test rating.

Soils testing rare response (RR) or no response (NR) for phosphorus contain more plant-available phosphorus than required for most crops.

Where manure is used, decrease the fertilizer rate accordingly. For more details, see Table 1-8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10.

Table 1-11. Phosphorus and Potassium Requirements: Vegetables on Muck Soils

Phosphorus					Potassium				
Phosphorus Soil Test¹ mg P/ L of soil	Rating*	Phosphate required kg P₂O₅/ha			Potassium Soil Test² mg K/ L of soil	Rating*	Potash required kg K₂O/ha		
		Beets Broccoli³ Brussels sprouts³ Cabbages³ Carrots Cauliflower³	Lettuce Onions⁴ Parsnips Potatoes Radishes Spinach	Celery			Broccoli Brussels sprouts Cabbages Cauliflower	Carrots Celery Onions Parsnips Potatoes	Beets Lettuce Radishes Spinach
0-3	HR	100		120	0-15	HR	200	230	100
4-5		100		120	16-30		190	220	100
6-7		100		120	31-45		170	210	90
8-9		100		120	46-60		150	200	80
10-12	MR	90		120	61-80	MR	120	170	60
13-15		90		110	81-100		90	150	40
16-20		80		100	101-120		70	120	30
21-25		70		90	121-150		50	80	20
26-30	LR	60		80	151-180	LR	40	40	20
31-40		50		70	181-210		0	0	0
41-50		30		50	211-250		0	0	0
51-60		20		40	250+		0	0	0
61-80	RR	0		0					
80+	NR	0		0					

* HR = high response MR = medium response LR = low response RR = rare response NR = no response

¹ Sodium bicarbonate (Olsen) extraction method

² Ammonium acetate extraction method.

³ For transplanted broccoli, Brussels sprouts, cabbages and cauliflower, if no insecticide is used in the planting water, apply a starter solution high in nitrogen, such as 20-20-20 at 1 kg/200 L. Under high temperatures and in dry, sandy soils, use half the concentration of fertilizer.

⁴ If maturity of onions is a problem on organic soils less than 40 cm deep, additional phosphate may be required.

Sources of Phosphorus

Synthetic Fertilizers

The most common sources of fertilizer phosphorus are outlined in Table 1-7, *Fertilizer Materials: Primary Nutrients*, on page 9.

Mono-ammonium phosphate (MAP) is a very effective source of fertilizer phosphorus. In addition to the phosphorus, it contains 11% nitrogen (ammonium.) The presence of ammonium-nitrogen can help improve the plant's ability to absorb phosphorus. When using MAP, be sure to decrease the amount of nitrogen fertilizer used accordingly. Excess nitrogen, especially in fruiting vegetables, may result in too much leaf growth and decreased fruit yields.

Manure

When properly applied, manure is an excellent, inexpensive source of phosphorus. It also supplies the soil with valuable organic matter and micronutrients. Table 1-8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, provides the

approximate amount of crop-available phosphorus contained in manure.

Unlike nitrogen, the phosphorus in manure can be held by the soil over a considerable period of time. The application of large quantities of manure over time may result in a build-up of phosphorus in the soil. The long-term impact of manure applications is best estimated by soil testing. Avoid making heavy manure applications on soils testing rare response (RR) or no response (NR) for phosphorus (see *Phosphorus in the Environment*, on page 11).

Manure can pose a food safety risk on many vegetable crops. Ensure at least 120 days between manure application and harvest. See *On-Farm Food Safety*, on page 45.

Phosphorus Application Methods

Phosphorus fertilizers are commonly broadcast prior to planting. Phosphorus does not move in the soil water.

A broadcast application will help ensure that adequate phosphorus levels are evenly distributed throughout the crop rooting zone. Side-dress applications of phosphorus are not generally recommended. See *Starter Fertilizers for Vegetable Crops*, on page 6.

Fertigation

Many common forms of phosphorus are not suitable for use in fertigation systems. Most phosphate fertilizers will form salts when mixed with other nutrients. These salts will plug the emitters, rendering the whole system useless. Water-soluble forms of phosphorus have been developed for the greenhouse industry. However, in field conditions, there is no yield advantage associated with the application of phosphorus through drip irrigation. The presence of phosphorus may also encourage the growth of algae in the drip tape, consequently plugging the emitters. Soil applications remain the most cost-effective method of delivering phosphorus to the crop.

Potassium

Potassium (K) is an important component of plant cells. It also influences the uptake of water by the roots and plays a role in both respiration and photosynthesis. The sugar and starch content of potato and tomato crops may be affected by potassium levels.

Most crops require equal amounts of potassium and nitrogen. Excessive potash applications may negatively impact the crop's ability to remove calcium and magnesium from the soil. Where soil potassium levels are high, calcium and magnesium deficiencies may occur.

Visual Deficiency Symptoms

Potassium deficiency usually appears on the older leaves first. It can cause a yellowing or burning of the leaf margins. In tomatoes, low potassium levels have been associated with yellow shoulders on ripe fruit. In other fruiting vegetables, severe potassium deficiencies may result in misshapen fruit and increased levels of fruit abortion. Insufficient levels of potassium can reduce the shelf-life of many vegetable crops.

Potassium Recommendations

Crop-specific recommendations are outlined in Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, previous page, and Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, opposite page.

These recommendation tables should only be used with OMAFRA-accredited ammonium acetate extraction soil

tests. Non-accredited tests may use different procedures, resulting in inappropriate recommendations if used with the OMAFRA tables. Fertilizer rates in this table are designed to produce high economic yields when accompanied by good or above average management.

Where a soil test is not available, use the following guidelines to obtain a rough estimate of requirements from these tables:

- If the field has been fertilized regularly for a number of years, or heavily in recent years, use one of the rates recommended for the medium response (MR) soil test rating.
- If the field has received little fertilizer in the past, use one of the rates recommended for a high response (HR) soil test rating.

Some clay and clay loam soils are naturally high in potassium and do not require any potash fertilizers. Only a soil test can adequately determine potash requirements.

Sources of Potassium

Synthetic Fertilizers

The most common sources of fertilizer potash are outlined in Table 1–7, *Fertilizer Materials: Primary Nutrients*, on page 9.

Manure

Manure is an excellent, inexpensive source of potassium. It also supplies the soil with valuable organic matter and micronutrients. Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, lists the approximate amount of crop-available potash contained in manure.

Unlike nitrogen, the potassium found in manure can be held by the soil over a considerable period of time. The application of large quantities of manure over time may result in a build-up of potash in the soil. The long-term impact of manure applications is best estimated by soil testing.

For most vegetable crops, apply manure at least 120 days before harvest. For more information on food safety concerns in vegetable crops, see *On-Farm Food Safety*, on page 45.

Potash Application Methods

Potash fertilizers are commonly broadcast prior to planting. Where a drip irrigation system is being used, a significant portion of the fertilizer may be applied as fertigation.

Table 1-12. Potassium Requirements: Vegetables on Mineral Soils

Potassium Soil Test ¹ (mg K/ L of soil)	Rating*	Potash (K ₂ O) Required kg/ha									
		Radishes	Beans (snap & lima) Peas	Sweet corn	Sugarbeets ²	Tomatoes (paste & fresh market) Cucumbers Muskmelons Pumpkin Squash Watermelons	Beets Carrots Lettuce Onions Parsnips Potatoes Spinach Horseradish	Broccoli Brussels sprouts Cabbages Cauliflower Eggplant Peppers	Celery Rhubarb Rutabagas ³	Asparagus	Tomatoes ³ (whole pack)
0-15	HR	60	120	170	180	230	230	270	340	420	660
16-30		60	110	160	170	220	220	250	330	400	640
31-45		50	90	140	160	200	210	230	310	360	600
46-60		50	80	110	140	180	190	200	280	320	560
61-80	MR	40	60	80	120	140	160	170	250	280	480
81-100		30	40	50	90	100	130	130	200	250	400
101-120		30	30	30	70	70	100	100	150	220	340
121-150		20	0	0	20	50	80	80	90	190	300
151-180	LR	20	0	0	0	40	50	50	50	160	280
181-210		0	0	0	0	0	0	0	0	130	140
211-250		0	0	0	0	0	0	0	0	80	70
250+		0	0	0	0	0	0	0	0	0	0

* HR = high response MR = medium response LR = low response RR = rare response NR = no response

¹ Ammonium acetate extraction method.

² Excess application of potassium will lead to luxury consumption by the sugarbeet plant. This has a negative effect upon clear juice purity.

³ For rutabagas and tomatoes on soils with magnesium tests less than 100, the required amount of potash is adjusted downward from the amounts shown in this table to a minimum of 50% at 50 ppm Mg.

Fertigation

Where crops are grown under fertigation, apply approximately half the potash requirement prior to planting. The remainder can be injected through the fertigation system.

Recommended application rates for fertigated tomatoes, peppers and cucurbit crops appear in the commodity sections of Chapter 9.

For more information, see Chapter 3, *Water Management*, on page 27, and *Fertigation*, on page 30.

Calcium

Calcium is a vital component of cell walls and is involved in the formation and metabolism of the cell nucleus. Calcium pectate in the cell walls provides a physical barrier to disease entry. Calcium does not move readily within the plant.

Visual Deficiency Symptoms

Calcium deficiencies may result in the death of the plant's growing point. It may also cause the blossoms and buds to drop prematurely.

Fertilizer Recommendations

Calcium deficiencies rarely occur in vegetables grown on soils with a pH of 6.0-7.5. Foliar applications may be warranted on coarse sandy loam soils, where the pH is at the low end of this range. See Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, next page.

Management Notes

Calcium-related disorders may occur in some crops (e.g., blossom-end rot in tomatoes and watermelon, blackheart in celery or tipburn in lettuce and cabbage). Calcium enters the plant through the transpiration stream. If the water supply is limited, calcium tends to accumulate in the large leaves where the water requirement is greatest. Under these conditions, the dissolved calcium bypasses the fruit and developing leaves, which have lower transpiration rates.

Several cultural management practices will reduce the occurrence of calcium-related disorders. Efficient nitrogen use will help prevent excessive vegetative growth. Good soil management practices ensure good root growth, promoting both water and nutrient uptake. Timely irrigation will help maintain a steady supply of calcium throughout the plant.

Table 1–13. Magnesium, Calcium and Micronutrient Fertilizer Sources¹

Nutrient	Source	% Nutrient	Other Nutrients	Application	
				Soil	Foliar
Calcium (Ca)	calcium chloride	36%	64% chloride	✓	✓
	calcium nitrate	19%	15.5% nitrogen	✓	✓
Magnesium (Mg)	dolomitic limestone	6%–13%	16%–22% calcium	✓	
	epsom salts	9%	13% sulphur	✓	✓
	sulphate of potash magnesia	11%	22% K ₂ O, 20% S	✓	
Boron (B)	various granular materials	12%–15%		✓	
	sodium borate	12%–21%		✓	✓
	Solubor	20%			✓
Copper (Cu)	copper sulfate	13%–25%		✓	
	copper chelates	5%–13%			✓
Iron (Fe)	ferrous sulphate	20%			✓
	iron chelates	3%–13%			✓
Manganese (Mn)	manganese sulfate	28%–32%			✓
	manganese chelates	5%–12%			✓
Molybdenum (Mo)	sodium molybdate	39%			✓
Zinc (Zn)	zinc sulfate	36%		✓	✓
	zinc oxysulfate	8%–36%		✓	
	zinc chelate	9%–14%			✓

¹ A number of micronutrients are available as chelates, with various formulations and nutrient contents. Check the product labels for crop specific recommendations. The effective rate for chelated products is the same as for other formulations.

Magnesium

Magnesium is an essential part of the chlorophyll molecule and aids in the formation of sugars, oils and fats.

Visual Deficiency Symptoms

Magnesium deficiency usually appears on the older leaves first. The leaf tissue between the veins turns yellow, while the veins remain green. A severe deficiency will cause leaf margins to curl.

Fertilizer Recommendations

See Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, this page. Apply magnesium according to Table 1–14, *Magnesium Soil Test Ratings and Interpretations for All Crops*, this page.

Table 1–14. Magnesium Soil Test Ratings and Interpretations for All Crops

Soil Magnesium ¹ mg/L of soil (ppm Mg)	Rating	Recommendation
Below 20	HR	Apply magnesium for all crops. If pH is below 6.5, apply dolomitic lime. At higher pH values, apply 30 kg soluble magnesium (Mg) per hectare. Potash applications in excess of those recommended by a soil test will increase the probability of Mg deficiency.
20–39	MR	If lime is required, use dolomitic. Magnesium is recommended if potassium soil test is above 250. Potash applications in excess of those recommended by a soil test will increase the probability of magnesium deficiency.
40–100	MR	If lime is required, use dolomitic.
100+	LR	If lime is required, use either dolomitic or calcitic.

¹ 1 M ammonium acetate extraction method.

Management Notes

If the soil pH is below 6.5, the most effective and economical means of supplying magnesium is with applications of dolomitic limestone. If the pH is above 6.5, and the soil test result is 20 ppm or below, magnesium can be supplied by either magnesium sulfate or sulfate of potash magnesia. Excessive potassium applications may induce a magnesium deficiency.

For tomatoes and rutabagas on soils with magnesium tests of less than 100 ppm, adjust the amount of potash recommended downward to a minimum of 50% at a magnesium test of 50 ppm. For example, a soil testing 75 ppm magnesium should receive only 75% of the usual potash recommendation for that soil. On soils testing 50 ppm magnesium or less, apply 50% of the total potash recommendation.

Sulphur

Sulphur is an important component of chlorophyll. It aids in seed production and is involved in nitrogen fixation in legumes. Sulphur adds flavour, colour and distinctive odours to several vegetable crops including brassica crops, onions, garlic and horseradish.

Visual Deficiency Symptoms

Sulphur deficiency is very similar to nitrogen deficiency. Affected plants are often stunted and have pale foliage. Sulphur deficiency may delay maturity. Nitrogen

deficiency usually appears on the older leaves first, while sulphur deficiency will affect the entire plant.

Fertilizer Recommendations

There is no OMAFRA-accredited soil test for sulphur. Soil sulphur levels fluctuate over the course of the growing season depending on soil temperature, moisture and organic matter. Historically, sulphur was a component of many synthetic fertilizers. Modern production methods have removed much of the sulphur found in fertilizer. Nevertheless, many Southwestern Ontario farms still receive considerable amounts of sulphur in the form of acid rain. Each year, 8–13 kg/ha of sulphur are deposited in rainfall.

Deficiencies occasionally occur on coarse, sandy-loam, low pH soils. On these soils, apply calcium sulphate. Improving soil organic matter will also help increase soil sulphur levels. Many livestock manures also contain significant amounts of sulphur.

Micronutrients

Micronutrients include boron, copper, iron, manganese, molybdenum and zinc. Plants use these elements in smaller amounts than the major nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium. But they are still very crucial to a plant's overall nutrition.

Micronutrients are usually found in much lower levels in the soil than macronutrients. Soil pH, organic matter, clay content and mineralogy can influence the results of the micronutrient soil test. This makes estimating micronutrient availability less reliable than the evaluation of the major nutrients.

Crop Response to Micronutrient Fertilizers

Crops vary in their response to micronutrients. Highly responsive crops will often respond to additional micronutrients if the soil micronutrient concentration is low. Medium-responsive crops are less likely to respond, and low-responsive crops do not usually respond to fertilizer additions, even at low soil micronutrient levels.

Table 1–15, *Response of Crops to Micronutrient Fertilizers*, this page, outlines the response of various vegetable crops to micronutrient fertilizers. A high rating does not mean the crop always needs additional micronutrients. Response to any given nutrient only occurs when the soil is already low in that nutrient.

Table 1–15. Response of Crops to Micronutrient Fertilizers¹

Crop	Mn	B	Cu	Zn	Mo	Fe
Asparagus	Low	Low	Low	Low	Low	Med
Beans, snap	High	Low	Low	High	Med	High
Beets, table	High	High	High	Med	High	High
Broccoli	Med	High	Med		High	High
Cabbages	Med	Med	Med	Low	Med	Med
Carrots	Med	Med	Med	Low	Low	
Cauliflower	Med	High	Med		High	High
Celery	Med	High	Med		Low	
Cucumbers	High	Low	Med			
Lettuce	High	Med	High	Med	High	
Oats	High	Low	High	Low	Low	Med
Onions	High	Low	High	High	High	
Parsnips	Med	Med	Med		Low	
Peas	High	Low	Low	Low	Med	
Peppers	Med	Low	Low		Med	
Potatoes	High	Low	Low	Med	Low	
Radishes	High	Med	Med	Med	Med	
Rye	Low	Low	Low	Low	Low	Low
Spinach	High	Med	High	High	High	High
Sugarbeets	High	Med	Med	Med	Med	High
Sweet corn	High	Med	Med	High	Low	Med
Tomatoes	Med	Med	High	Med	Med	High
Turnips	Med	High	Med		Med	

Mn = Manganese B = Boron Cu = Copper
Zn = Zinc Mo = Molybdenum Fe = Iron

¹ Taken, with permission, from the Michigan State University Cooperative Extension Publication E486 *Secondary and Micronutrients for Vegetables and Field Crops* (Table 3, *Relative response of selected crops to micronutrient fertilizers*).

Use caution when applying mixtures of several micronutrients, as crop injury may occur. Always follow the product label. Do not combine micronutrients with insecticide, fungicide or herbicide sprays unless there is information from the manufacturer of each product indicating that the mixtures are compatible. Many chelated micronutrients will consolidate in the spray tank if mixed with pesticides. Boron fertilizers will react with solupaks.

Use caution when applying micronutrients through fertigation systems. Certain micronutrient blends may cause the emitters to plug.

The use of micronutrients in the starter fertilizer is generally not recommended, as they often increase the amount of phytotoxicity, especially in adverse weather conditions.

Boron

Boron plays an important role in the structure of cell walls, fruit set and seed development. It is also important in protein and carbohydrate metabolism.

Visual Deficiency/Toxicity Symptoms

Boron deficiency symptoms vary widely between crops. In rutabaga and turnips, boron deficiency causes brown watery areas or hollow centres in the roots. Boron-deficient celery plants develop cracked stems, often with brown "cat scratches" and blackened hearts. In brassica crops, the deficiency causes hollow stems and brown curds. Sugarbeets, table beets and spinach all develop yellow leaves with cracking on the roots.

Boron toxicity may occur when sensitive crops are planted in a rotation where boron has been applied (or over-applied). The toxicity symptoms include spot-like, striped or blotchy yellowing on the leaves. This leads to the death of the tissue, usually beginning at the leaf tips and margins of older leaves. Under severe conditions, this will eventually develop over the whole plant.

Fertilizer Recommendations

There is no OMAFRA-accredited soil test for boron. Some other soil tests will report a soil boron value. Actual soil levels are often less than 1 ppm, making it very difficult to get an accurate measurement.

On request, fertilizer manufacturers may mix boron sources with ordinary fertilizers. **Do not band boron.** Foliar-applied sprays generally give faster and more effective results. Spray when the young plants are about 8 cm high. A second application may be required. See Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Management Notes

Some crops, such as cucurbits, sweet corn and seed corn, are very sensitive to boron, even at low levels. Consider the sensitivity of all rotational crops when applying boron. A soil pH between 5.0 and 7.0 provides the best conditions for boron uptake. Boron deficiencies are more likely to occur on soils with low organic matter and on exposed or eroded subsoils. Boron availability decreases during periods of drought.

Copper

Copper is required for chlorophyll production. It may also have a role in the suppression of some diseases.

Visual Deficiency Symptoms

Copper deficiencies are most common in crops grown on organic (muck) soils. In carrots, it causes pale roots. In onions it causes dieback and curling of the leaf tips.

Copper-deficient onions may also have pale bulbs with thin scales. Copper-deficient lettuce leaves lose firmness and develop bleached yellow stems.

Fertilizer Recommendations

There is no OMAFRA-accredited soil test for copper. Soil tests are unreliable on Ontario soils. Plant analysis is a more useful tool. If copper is required, see Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16. Use extreme care in applying copper sulphate to leaves, as phytotoxicity can occur. Always follow the labelled rates and precautions.

Management Notes

Copper availability may be lower on muck soils and also on coarse sands with very low organic matter. Copper availability decreases as soil pH increases.

The addition of copper to muck soils helps slow the subsidence of the soil. When organic soils are first brought into cultivation, apply copper to the soil at 14 kg copper/ha for each of the first 3 years. Make subsequent applications of 5 kg copper/ha every second year thereafter.

Iron

Iron is needed for chlorophyll formation, plant respiration and the formation of some proteins.

Visual Deficiency Symptoms

Iron deficiency first appears as yellowing between the veins of the newest growth. The veins will remain green except in extreme cases.

Fertilizer Recommendations

There is no OMAFRA-accredited soil test for iron. An iron soil test does not correlate well with plant uptake or fertilizer response in Ontario. Plant analysis is a much more reliable indicator of iron availability.

Management Notes

Iron deficiencies are rare in Ontario. Factors associated with iron deficiency in other parts of the world are extreme imbalances with other metals such as molybdenum, copper or manganese. Excessive phosphorus in the soil may also contribute to lack of iron availability. Soil with low organic matter or a combination of high pH, high lime and wet, cold soils can induce iron deficiency symptoms in sensitive crops.

Manganese

Manganese is involved in photosynthesis and chlorophyll production. It helps activate enzymes involved in the distribution of growth regulators within the plant.

Table 1-16. Manganese Requirements

Manganese Index ¹	Manganese (Mn) Required ² kg/ha	
	Onions, Lettuce, Beets	Other Crops
0-7	2	0 ³
8-15	2	0
16-0	0	0
50 + Above Normal	0	0

¹ Manganese Index = $498 + 0.248$ (phosphoric acid extractable Mn in mg/L of soil) - 137 (soil pH) + 9.64 (soil pH)²

² Apply manganese as foliar spray of manganese sulphate. Soil applications are inefficient.

³ The manganese soil test is low, however manganese deficiency is not expected on crops other than onions, lettuce and beets. If deficiency symptoms appear, make a foliar application of 2 kg Mn/ha in 200 L water (1.8 lb Mn/acre in 18 gal water.)

Visual Deficiency/Toxicity Symptoms

Manganese deficiency causes yellowing between the veins of young leaves. Leaves gradually turn pale-green with darker green next to the veins.

Manganese toxicity can occur on soils with a low pH. It causes brown spots or yellow, mottled areas near leaf tips and along the leaf margins. It usually develops on older leaves. Brown spots may also develop on veins, petioles and stems.

Fertilizer Recommendations

The OMAFRA-accredited manganese soil test uses a manganese availability index. This index evaluates manganese availability based on soil manganese level and soil pH. See Table 1-16, *Manganese Requirements*, this page, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Management Notes

Manganese availability is greatest at a soil pH of 5.0 to 6.5. Maintain the target pH levels as outlined in Table 1-3, *Soil pH at Which Lime Is Recommended for Ontario Field-Grown Crops*, on page 4. It is important not to add more lime than is needed to correct soil acidity. High organic matter levels decrease manganese availability.

Soil-applied manganese may be useful in acidic (low pH) sandy soils; however, on high pH and muck soils, foliar applications are often more effective than soil applications. If a manganese deficiency is confirmed, apply foliar sprays when the plants are about one-third grown or sooner. Two or more sprays may be necessary at 10-day intervals.

Molybdenum

Molybdenum plays an important role in nitrogen metabolism within the plant. It is involved with nitrogen fixation in legumes. It also plays a role in pollen viability and seed production.

Visual Deficiency Symptoms

Early deficiency symptoms are similar to nitrogen or sulphur deficiency. Affected plants become stunted and lack vigour. Leaves may turn brown along the margins. Molybdenum deficiency causes cupping (whiptail) in cauliflower. Deficiency in legumes leads to poor nodule formation.

Fertilizer Recommendations

There is no OMAFRA-accredited soil test for molybdenum. Deficiencies are best confirmed with a plant analysis. If molybdenum is required, see Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

See the individual commodity sections of Chapter 9, starting on page 67, for recommended application methods and rates for brassica crops and onions.

Management Notes

Molybdenum availability improves with increasing soil pH. Liming can improve availability on acid soils. Deficiencies may also occur under low soil moisture conditions.

Zinc

Zinc is important in early plant growth and in grain and seed formation. It also plays a role in chlorophyll and carbohydrate production.

Visual Deficiency Symptoms

Zinc is relatively immobile within the plant. Deficiency symptoms appear first on younger leaves. Young leaves become mottled and show interveinal chlorosis, striping or banding. Some crops are more susceptible than others. Symptoms are listed below.

Sweet corn

Pale yellow or white bands form between the leaf margin and mid-vein in the lower part of younger leaves. Severely deficient plants have "white bud," where new leaves emerge from the whorl completely white.

Legumes

Typical symptoms are thin, short stems and/or pale-green, bronzed foliage with yellow discolouration. Eventually the leaves turn a mottled yellow while the veins remain darker green.

Onions

Stunted growth with twisted, yellow-striped foliage are the usual symptoms.

Fertilizer Recommendations

The OMAFRA-accredited soil test for zinc reports a zinc soil index value. This index evaluates zinc availability based on the soil zinc level and soil pH.

Zinc deficiency can be prevented by the application of zinc fertilizer to the soil. See Table 1–17, *Soil-Applied Zinc Requirements*, this page.

Early in the growing season, use foliar sprays to correct a deficiency after the symptoms have appeared. Foliar applications of zinc are not recommended for sweet corn, as zinc is relatively immobile in the plant, and soil zinc is better able to supply the needs of the developing ears. See Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Table 1–17. Soil-Applied Zinc Requirements

Zinc Index ¹	Zinc (Zn) Required kg/ha	
	Corn, Onions	Other Crops
0–7	4–14 ²	0 ³
8–14	4–14 ²	0
15–100	0	0
100 + Above Normal	0	0

¹ Zinc index reported = $203 + 4.5$ (DTPA extractable soil zinc in mg/L of soil) – 50.7 (soil pH) + 3.33 (soil pH)²

² The 14 kg Zn/ha rate should be sufficient for up to 3 years. Do not apply more than 4 kg Zn/ha as a banded application.

³ The zinc soil test is low, however zinc deficiency is not expected on crops other than onions and sweet corn. If zinc deficiency symptoms appear, make a foliar application.

Management Notes

Zinc deficiencies are most often seen on sandy soils with high pH levels. Crops on heavily eroded soils may also show zinc deficiency symptoms. Large applications of phosphorus may aggravate zinc deficiencies. Livestock manure is often an excellent source of zinc. Manure can pose a food safety risk on many vegetable crops. Ensure at least 120 days between manure application and harvest. See *On-Farm Food Safety*, on page 45.

2. Soil Management

Vegetable production is a very intensive process, usually involving a lot of tillage and numerous passes over a field. Most prime vegetable-growing soils are light in texture; maintaining soil organic matter levels and soil quality is a challenging and ongoing process. Soil organic matter contributes to soil structure, enhances the soil's capacity for holding moisture, increases the soil's ability to hold nutrients and improves drainage. Maintaining adequate soil organic matter levels will help support crop yields, particularly under adverse conditions.

Soil Quality

Soil quality is the measure of a soil's health and its ability to resist erosion, compaction and other stresses, while maintaining economic productivity. Many factors determine a soil's health. A healthy soil:

- has good soil structure and minimal compaction
- resists crusting
- has an abundance of earthworms
- smells good
- readily decomposes residue
- has good drainage, water movement and water-holding capacity
- encourages seedling emergence and root growth
- produces uniform crop growth and colour
- has optimal ranges of nutrient levels, pH and organic matter
- is resistant to wind, water or tillage erosion

The optimum soil organic matter level varies, depending on soil type.

Soil type	Optimum soil organic matter level
sandy	2%–4%
sandy-loam	3%–4%
loam	4%–5%
clay-loam	4%–5%
clay	4%–6%

Assessing the soil quality for each field and taking steps to maintain or improve it will ensure long-term productivity. Maintaining soil quality is a continuous process. Some measures are easy and relatively inexpensive, while others require more effort and commitment. Table 2–1, *Maintaining or Improving Soil Quality*, next page, describes a variety of measures that can be used to help maintain or improve various aspects of soil quality.

For further information on soil management, see:

- OMAFRA Publication 811, *Agronomy Guide for Field Crops*
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Soil Management*, Order No. BMP06.

For more information on composting, see the OMAFRA Factsheet, *Agricultural Composting Basics*, Order No. 05-023.

Subsidence of Peat and Muck Soils

Cultivated peat and muck soils decompose or subside (oxidize) gradually at rates of 1–3 cm/year. Maintaining a high water table and a pH of 5.1–5.5 reduces the rate of subsidence to less than 0.05 cm/year. A very wet (or very acidic) soil does not give maximum yields and is likely to be flooded when rainfall is intense. Wet spots may also be difficult to work and may result in uneven crop growth. Keeping fields well drained during the growing season will ensure optimal crop growth. Raising the water table in the fall and winter will help reduce the rate of subsidence.

Copper (Cu) applied as fertilizer has the residual effect of slowing down degradation (subsidence) by about 50%. Apply 14 kg of Cu/ha annually to peats and mucks in the first 3 years of cultivation and up to 5 kg of Cu/ha every second year thereafter, particularly when onions, carrots or lettuce are grown on the soils.

Table 2–1. Maintaining or Improving Soil Quality

Measure	Comments
Easy/less expensive	
Use of cover crops	Use cover crops with fibrous root systems to improve soil structure, particularly in the seed bed. Use cover crops with tap roots to penetrate dense soil layers. Cover crops provide protection from wind and water erosion. Cover crops add active organic matter to support beneficial soil organisms.
Soil testing and accurate application of fertilizer and lime	Adequate pH and fertility will improve crop growth.
Reducing tillage and using residue management	Using fewer tillage passes to prepare the seedbed will: - leave more residue on the surface to protect against wind and water erosion - reduce soil organic matter loss - reduce crusting by leaving soil aggregates intact
Adding organic matter in the form of manure or compost	Regularly adding organic materials to the soil will help increase organic matter levels in the soil, improve soil structure, increase the water-holding capacity and make the soil less prone to erosion. Manure is also a valuable source of nitrogen, phosphorous, potassium and many micronutrients.
Erosion control measures	Simple measures such as buffer strips, drop structures (rock chutes or drop pipes), tile outlet protection and strip cropping greatly reduce soil erosion. Structures such as water and sediment control basins and terraces help to slow water movement across fields, preventing major soil loss.
Significant management changes or investment required	
Minimum tillage	Switching to minimum or no-till systems will leave more residue on the soil surface and help prevent erosion. It will also improve soil structure. This requires investment, equipment and management changes.
Crop rotation, including a mix of cereal, legume or grass crops	Rotating vegetable crops over a period of 2–4 years with cereals, legumes or forages will improve soil structure, improve the water-holding capacity and make the soil less prone to erosion.
Planting windbreaks	Treed windbreaks protect the soil and prevent sandblasting and desiccation of the crop. They may also provide the benefits of a microclimate. Results are seen in a few short years after planting, and the benefits can last a lifetime.
Planting windstrips	Established each year, grass wind strips can be adapted to many different crops. Similar to windbreaks, windstrips protect the soil and prevent sandblasting and desiccation of the crop and may provide microclimate benefits.
Improving drainage	Tile drainage will remove excess water, allowing for more timely field operations, reduced compaction potential and improved crop growth.

Tillage Systems

The traditional role for tillage has been to provide weed control and to prepare a seedbed that will give good crop stands and high yields. More recently, tillage and cropping systems have been changed to accomplish the same goals while reducing soil erosion through less intensive or no cultivation. Newer, more effective herbicides have reduced the need for aggressive mechanical weed control programs. Other factors favouring reduced tillage are savings on fuel and labour.

Base any decision to switch to a different tillage system on the system's compatibility with the farm's soil types, slopes, drainage, spring soil temperatures and the crop rotation. Tillage impacts erosion control as well as the timeliness of field work and the potential for controlling weeds, insects and diseases.

No one tillage system is best for all Ontario conditions. Variability in soils, crops, climate and management mean tillage systems must be fine-tuned for each farm

operation. In fact, the tillage system may rotate with the crop, allowing for the use of the most appropriate tillage for each crop.

Vegetable crops grown successfully in no-till and conservation tillage systems include:

- tomatoes
- sweet corn
- pumpkins
- squash
- brassica crops
- peppers
- snap beans

Conventional Tillage

Conventional tillage is any system that attempts to bury most of the previous crop residue, leaving less than 30% of the soil surface covered with residue after planting. Usually, a moldboard plow is used in conjunction with a variety of other tillage implements.

The principal advantages of the moldboard system are that the machinery is familiar and widely available, and the system is adaptable to a wide range of soil conditions. Moldboard plowing increases soil porosity, allowing for air exchange, root proliferation and water infiltration, especially when rainfall is above average. However, the increased porosity can be lost with excessive secondary tillage, soil compaction or in soils with poor structural stability. Many livestock producers view the moldboard plow as the most effective tool for incorporating manure and breaking up sod fields.

The main weaknesses of the moldboard system include high costs of equipment, fuel and additional labour associated with seedbed preparation. With little or no residue cover, there is a high risk for soil erosion by wind and water. Adjusting the moldboards so that the soil is not completely inverted and some residue is left on the surface can help reduce some of these problems.

Conservation Tillage

Conservation tillage systems are designed to leave residue from the previous crop on the soil surface, providing more protection against erosion than conventional tillage. A variety of implements can be used for conservation tillage. The chisel plow has been the most widely adopted conservation tillage tool in Ontario. Tandem and offset discs are also used extensively in some areas of the province.

Fall chisel plowing with twisted shovel teeth will often leave ridges in the field the following spring. This can lead to extra costs in secondary tillage (more passes), uneven seed beds and occasionally excessive soil drying. Many of these problems can be overcome by:

- using sweep teeth on all or part of the chisel plow
- adding a levelling bar or harrows to the rear of the chisel plow
- practicing timely secondary tillage in the spring

Zone Tillage

Zone tillage (also known as strip tillage) combines the best of both no-till and conventional tillage systems. It uses both shanks and coulters to create a narrow (15–20 cm wide) zone of tilled soil that acts as a well-prepared seedbed. Each zone of tillage corresponds to the width of the planter units. The area between the rows is left undisturbed. This dramatically increases the amount of surface residue left on the field, while still creating the fine seed bed desired by many vegetable growers.

Zone tillage may be done in the fall, to aid in the timeliness of field work the following season, or in the spring, immediately before planting. Crops such as sweet corn and pumpkins are well suited to this system.

No-Till Systems

No-till systems provide the greatest opportunity to leave protective crop residues on the soil surface. They also have the greatest potential for reducing the cost of labour and fuel on the farm. One drawback of no-till is the increased reliance on "burndown" herbicides.

Numerous options exist, both in the original design and in the modifications available for row crop planters or seed drills to be considered capable of "no-till." Several Ontario equipment companies are leading the industry in the development of no-till vegetable planters.

No-till is a technique that can be used relatively easily with some vegetable crops. Maintaining surface crop or cover crop residues offers several benefits, including:

- the potential for weed suppression
- interference with the movement of some pests, e.g., Colorado potato beetle
- reduction of sand blasting and wind desiccation
- reduction of soil water losses

However, concerns with insects and diseases, precision seeding and crop debris during machine harvest remain a challenge for many vegetable crops.

Tillage serves a slightly different purpose in organic vegetable production. Organic growers may rely heavily on timely cultivation to provide weed control. In certain organic crops, combining weed-suppressing cover crops with no-till practices may provide suitable weed suppression.

For further information on tillage systems, see the OMAFRA/Agriculture and Agri-Food Canada booklets:

- *Best Management Practices — No-Till: Making It Work*, Order No. BMP11
- *Best Management Practices — Soil Management*, Order No. BMP06

Cover Crops

Cover crops play a major role in soil management by providing ground cover to reduce erosion and by adding organic matter to improve or maintain soil quality. Plant cover crops immediately after harvest to get the most benefit from the cover crop investment. While broadcast application and incorporation of cover crop seed works well to establish cover crops, direct seeding or drilling will ensure faster and more even establishment.

Several cover crops can be used. Each has its own strengths and weaknesses. See Table 2–2, *Selecting a Cover Crop*, this page, and Table 2–3, *Characteristics of Cover Crops Grown on Ontario Vegetable Farms*, opposite page. Cover crops can be divided into three groups based upon plant types: grasses, legumes and non-legume broadleaves.

Grasses

Grasses have fine, fibrous root systems that are well suited to holding soil in place and improving soil structure. Grass species suitable for cover crops are fast growing and relatively easy to kill (either chemically, mechanically or by winter temperatures). Grasses do not fix nitrogen out of the atmosphere, but they can scavenge quantities of residual nitrogen left in the field after harvest. Wind strips are usually created from overwintering grass cover crops.

Spring Cereals

Spring cereals are well suited for late summer and early fall plantings. Under good growing conditions, spring cereals will produce the greatest amount of crop biomass, making them valuable ground cover. Once well established, spring cereals are relatively tolerant of frost. Do not attempt to establish late in the fall as the growth will be limited.

Winter Cereals

Winter cereals are highly versatile cover crops. They can be planted in summer or in the fall for soil cover. Winter cereals usually survive the winter providing erosion protection the following spring. These grasses can be used to create windstrips, residue mulch or killed early to minimize residue cover at planting.

Warm Season Grasses

Warm season grasses like sorghum and millet are best suited for planting into the warmer soils of late June, July and early August. They are very sensitive to frost. Root growth is extensive and the top growth lush. Be prepared to mow these grasses to keep stalks tender, encourage tillering and prevent heading. Do not mow closer than 15 cm to ensure re-growth. Optimal growth may require additional fertilizer nitrogen.

Table 2–2. Selecting a Cover Crop

Function of the Cover Crop	Best Choice for Cover Crop
Nitrogen production	red clover or vetch
Nitrogen scavenging	Fall uptake – oilseed radish and other brassicas, oats Winter/spring uptake – rye, winter wheat
Weed suppression	oilseed radish and other brassicas, winter rye, buckwheat
Nematode suppression ¹	mustards – Cutlass Oriental, Indian sudans/sorghums – Sordan 79, Trudan 8 pearl millet – CFPM 101 marigold – Crackerjack, Creole oilseed radish – Adagio, Colonel
Soil structure building	oats, overwintered winter rye
Compaction busting	alfalfa, sweet clover
Biomass return to soil	Fall – oats, oilseed radish Summer – millets, sorghum, sudan
Erosion protection (wind or water)	winter rye, winter wheat, ryegrass (well established)

¹ Nematode suppression is specific to the variety of cover crop and the species of nematode.

Legumes

Legume cover crops can fix nitrogen from the air. They then supply it to the succeeding crop as well as protecting the soil from erosion and adding organic matter. The amount of nitrogen fixed varies from species to species. Generally, more top growth is an indicator of more nitrogen fixation. Ontario research has suggested that legume cover crops, such as red clover, are also effective at scavenging residual nitrogen from the soil.

Nitrogen release from legumes can be inconsistent. This must be accounted for when calculating fertilizer needs. See Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10. Excess nitrogen release late in the season could lead to excessive vegetative growth in fruiting vegetables, such as tomatoes, peppers and melons.

Some legume species, such as alfalfa and red clover, have aggressive tap roots that can break up subsoil compaction, but this requires more than one season's growth.

Table 2-3. Characteristics of Cover Crops Grown on Ontario Vegetable Farms

Species	Seeding Rate kg/ha	Normal Seeding Time	Nitrogen Fixed or Scavenged (F or S) ¹	Over-Wintering Characteristics	Building Soil Structure	Weed Suppression	Nematode Rating		Quick Growth	Root Type
							Root Lesion	Root-knot		
Grasses										
Spring cereals	100–125	Mid-Aug–Sept	S	Killed by heavy frost	Good	Good	+	–	Very fast	Fibrous
Winter wheat	100–130	Sept–Oct	S	Over-winters very well	Good	Good	+	–	Fast	Fibrous
Winter rye	100–125	Sept–Oct	S	Over-winters very well	Very good	Very good	+ ²	D	Very fast	Fibrous
Sorghum sudan	50	June–Aug	S	Killed by frost	Good	Good /fair	+	D	Very fast	Coarse fibrous
Pearl millet	4	June–Aug	S	Killed by frost	Good	Good/fair	D	–	Fast	Coarse fibrous
Ryegrass	12–18	April–May or Aug–early Sept	S	Annual, Italian partially survive; perennial over-winters	Very good	Fair/poor	–	–	Slow to establish	Fibrous
Broadleaves – Legumes ³										
Hairy vetch	20–30	Aug	F/S	Over-winters	Good	Fair/poor	++	+	Slow to establish	Tap with secondary fibrous
Red clover	8–10	March–April	F/S	Over-winters	Good	Fair	++	+++	Slow to establish	Weak tap/fibrous
Sweet clover	8–10	March–April	F/S	Over-winters	Good	Fair	–	–	Slow to establish	Strong tap
Soybeans	40–50	Aug	F/S	Killed by frost	Poor	Good/fair	–	–	Fast	Tap
Field peas	40–100	Aug	F/S	Killed by heavy frost	Poor	Good/fair	–	–	Fast	Weak tap/fibrous
Broadleaves – Non-Legume										
Buckwheat	50–60	June through Aug	S	Killed by first frost	Poor	Very good	+++	–	Fast	Weak tap/fibrous
Oilseed radish ⁴	10–14	Mid-Aug–early Sept	S	Killed by heavy frost	Fair	Very good	D	D	Fast	Moderate tap
Other brassicas, i.e., forage radish	Varies with species	Mid-Aug–early Sept	S	Species dependent, many killed by heavy frost	Fair	Very good	D	D	Fast	Moderate tap

100 kg/ha = 90 lb/acre

Nematode Rating Codes: - = poor or non-host + = ability to host D = certain varieties may help to decrease soil nematode populations

¹ The potential for nitrogen uptake is influenced by seeding date, stand establishment and growing conditions. Nitrogen-fixing legumes are less likely to take up residual nitrogen.² The rating for a full season rye crop would be higher (+++).³ Diseases caused by *Pythium* and *Phytophthora* species can be more severe after legume cropping.⁴ Oilseed radish residues can be toxic or allelopathic to subsequent crops if the following crop is planted too closely after green manuring. Allow the green manure residues to break down or desiccate before planting the next crop.

Non-Legume Broadleaves

These broadleaf crops cannot fix nitrogen from the air but they may absorb large quantities from the soil. Growth will be poor if soil nitrogen levels are low or if compaction is severe. These crops are not winter-hardy, so additional control measures are not normally required. Do not allow these crops to go to seed, as the volunteer seed can become a significant weed problem.

New and Emerging Cover Crops

New crops are frequently evaluated as cover crops. Often these species are from different parts of the globe and may not be well adapted to Ontario growing conditions. For more information on new and well known cover crop species, see the *Soil Management* section of the OMAFRA website at www.ontario.ca/crops or look at the regional pages from the Midwest Cover Crop Council at www.mccc.msu.edu.

Tillage Systems Following Cover Crops

In conservation and no-till cropping systems, cover crops can greatly increase the surface residue cover, adding to the potential benefits of the system.

Here are some management factors to consider when reduced tillage follows cover crops:

- Some regrowth of winter annual, biennial or perennial cover crops will occur in the following crop year. Usually this is easily controlled with normal herbicide treatments in the following crop. A controlled amount of regrowth (e.g., windstrips) can provide some spring wind protection.
- The first tillage operation with overwintering cover crops should occur at least 2 weeks prior to planting the main crop to allow for the breakdown of the residue to start.
- Seedbed preparation may be difficult if persistent cover crops are not tilled until spring or if they are allowed to grow too large.
- Cover crops that do not survive over winter may be an option, especially on more poorly drained soils or for crops that are planted very early in the spring.
- Consider burndown herbicides before conservation tillage of overwintering cover crops such as rye. Careful timing, rate and application of herbicides can help keep enough residue on the surface to prevent wind damage to tender crops while allowing crop establishment.

3. Water Management

Water is a valuable resource. A clean and abundant supply of water is critical to the success of the farm business and the health of the farm family. Farm operations influence water quality in many ways. Soil erosion, manure, septic system effluent, fertilizers, pesticides and fuel can affect surface and/or groundwater quality. Effectively managing these factors can have a positive effect on water quality. Farm woodlots, fence rows and buffer strips surrounding creeks and streams all add to the natural diversity of the Ontario landscape.

Improving Water Quality

The greatest water quality challenges involve bacteria, soil erosion, nitrates and phosphates. Problems can be minimized using the following practices.

Bacterial Contamination

- Contain runoff from cull piles, manure storages, livestock yards and silos.
- Avoid spreading manure on frozen or snow-covered ground.
- Make sure well heads and casings are properly maintained and protected from surface contamination.
- Ensure that the domestic septic system is working properly and is not discharging.

Soil Erosion

- Where possible, adopt the conservation tillage practices outlined in Chapter 2, *Soil Management*, on page 21.
- Install erosion-control structures.
- Use cover crops and wind-abatement crops.
- Maintain buffer strips surrounding creeks, streams and ponds to act as natural filters of sediment and soil-borne contaminants.

Nitrate and Phosphate Contamination

- Avoid spreading excessive amounts of manure or fertilizers.
- Use cover crops to capture residual nitrogen.
- Soil sample each field every 2–3 years and apply fertilizers according to the soil test recommendations.
- On soils with high phosphorous levels, use only low amounts as a starter fertilizer.

- Consider using the soil nitrate test to help determine nitrogen requirements.
- Reduce nitrogen fertilizer when the previous crop was a legume or when manure was applied.

For more information on protecting water quality, see:

- OMAFRA Factsheet, *Protecting the Quality of Groundwater Supplies*, Order No. 06-115
- OMAFRA Factsheet, *Environmental Impacts of Nitrogen Use in Agriculture*, Order No. 05-073
- OMAFRA Factsheet, *The Planning and Maintenance of an Erosion Control System*, Order No. 97-015
- OMAFRA Factsheet, *The Use of Earthen Berms for Erosion Control*, Order No. 99-047
- *Best Management Practices — Water Management*, Order No. BMP07
- *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13
- *Best Management Practices — Water Wells*, Order No. BMP12
- *Best Management Practices — Fish and Wildlife Habitat*, Order No. BMP10
- *Best Management Practices — Buffer Strips*, Order No. BMP15

Irrigation

Note: You must have a Permit to Take Water issued by the Ministry of the Environment to use more than 50,000 L of water in a day from either surface or groundwater sources.

Most vegetable crops require a uniform supply of moisture throughout the growing season. The average rainfall in Ontario is 70 mm/month during the growing season. For most vegetable crops, this provides only 65% of the water needed for optimum yield. Historically, moisture levels are often at their lowest in July and August when the crop water demand is at its highest.

Table 3–1. Vegetable Crop Rooting Depth

Shallow-Rooted (down to 30 cm)	Intermediate (30–60 cm depth)	Deep-Rooted (deeper than 60 cm)
celery	beans, snap	asparagus
cucumbers	broccoli	parsnips
lettuce	cabbages	pumpkins
onions	cauliflower	sweet corn
potatoes	carrots	watermelons
radishes	muskmelons	winter squash
	peppers	
	tomatoes	
	zucchini	

Common defects caused by moisture stress in vegetable crops include:

- blossom end rot
- growth cracks
- hollow heart
- fruit deformities
- tipburn
- poor seed/kernel development

Crops and Water Demand

Soil types differ in their ability to retain water following rainfall or irrigation. Water that is held by the soil and can be taken up by plants is called “available soil water” (ASW). The irrigation point for overhead irrigation systems occurs when the ASW within the crop’s rooting depth drops below 40%–60%. The trigger for drip irrigation systems is usually 85% ASW in the crop’s rooting zone. When the soil moisture drops below this point, crop yield and quality may be affected. The frequency of irrigation will depend on weather, crop rooting depth, crop growth stage, soil texture and the type of irrigation used.

Crop Rooting Depths

Vegetable crops vary in their response to irrigation. Shallow-rooted crops such as potatoes and celery require frequent, light irrigations. These crops will often respond to overhead irrigation when the ASW reaches 60%. Deep-rooted crops can use water from a greater volume of the soil profile and do not require irrigation as frequently. For these crops, overhead irrigation may often be delayed until the ASW reaches 40%–50%. Table 3–1, *Vegetable Crop Rooting Depth*, this page, shows the relative rooting depths of a number of vegetable crops.

Table 3–2. Critical Periods for Irrigation of Several Vegetable Crops

Critical Period	Crop
Flowering, pod setting	snap beans
Head formation and enlargement	broccoli cabbages cauliflower
Tasselling, pollination, ear filling	sweet corn
Bulb formation and enlargement	onions garlic
Flowering, fruit set and enlargement	cucumbers muskmelons watermelons zucchini eggplant peppers tomatoes

Critical Growth Stages

Most vegetable crops have growth stages during which drought stress can severely reduce yield and quality. Irrigation is especially important during these critical growth periods, which are listed in Table 3–2, *Critical Periods for Irrigation of Several Vegetable Crops*, this page.

Soil Water-Holding Capacity

Soil types vary in their ability to hold water. As seen in Table 3–3, *Average Available Soil Water Capacity (ASW)*, this page, coarse sands and loamy sands hold considerably less water than silt loams and silty clay loams. Soils with a low water-holding capacity often require weekly replenishment. Heavy applications may be wasteful, as these soils are not able to hold more than 25–33 mm of water at any given time.

Sandy loam and silt loam soils retain considerably more soil water. On these soils, it is possible to schedule heavier and less frequent irrigation.

Table 3–3. Average Available Soil Water Capacity (ASW)

Soil Texture	mm of water per mm of soil ¹
Sands	0.065
Loamy sand	0.085
Sandy loam	0.11
Loam	0.15
Silt loam	0.16
Silty clay loam	0.18
Clay loam	0.17
Clay	0.16

¹ Equivalent to inch of water per inch of soil.

Table 3-4. Average Intake Rate for Soil Textures

Soil Type	mm/hr
Sands	12-25
Loamy sand	7-20
Sandy loam	
Loam	
Silt loam	4-8
Silty clay loam	
Clay loam	
Clay	2-6

For an indication of the maximum amount of water available for the crop, multiply the average water capacity from Table 3-3 by the rooting depth found in Table 3-1. For example, the maximum amount of water available for a carrot crop grown on a sandy loam soil would be 66 mm ($600 \text{ mm} \times 0.11 = 66 \text{ mm}$). In this example, overhead irrigation should be applied once the crop's ASW has fallen below 50% (33 mm).

During the hot part of the growing season, irrigate more frequently. Likewise, during the cool part of the growing season, irrigate less often.

Application of unnecessarily high amounts of water wastes water and can cause leaching of fertilizers and pesticides. Apply water slowly to avoid runoff. The water application rate must not exceed the average intake rate for each soil type. See Table 3-4, *Average Intake Rate for Soil Textures*, this page.

Irrigation Systems

A number of types of irrigation systems have been adapted for use in vegetable crops. They include hand-moved sprinklers, travelling gun systems, centre-pivot and lateral systems, and drip (trickle) irrigation.

A more detailed description of each of these systems can be found in *Best Management Practices — Irrigation Management*, Order No. BMP08.

Irrigation Scheduling

Whichever type of irrigation system is used, it is important to schedule irrigation to avoid drought stress and provide water when it is most needed. Timely application of water will reduce the potential for nutrient loss or disease pressure due to excess water. There are two basic methods of scheduling irrigation: the water budget method and measuring soil moisture.

Water Budget Method

This method uses climatic data to estimate the amount of available water lost from the rooting

zone through crop use and evaporation. Crop water usage is calculated using the percentage of crop cover and the evapotranspiration (ET) rate from climatic data. Average daily ET rates from May through September are listed for several locations across Ontario in *Best Management Practices — Irrigation Management*, Order No. BMP08. Actual ET rates may be obtained from Weather INnovations Incorporated at www.weatherinnovations.com.

Measuring Soil Moisture

There are several tools available for measuring soil moisture content.

Tensiometers measure how strongly water is held by the soil. As the soil dries out, moisture is more strongly held to soil particles and less available to the crop. Tensiometers can be used to determine when moisture stress occurs, and thus when irrigation should be started. Irrigate sandy soils when soil moisture tension reaches 15–20 centibars. Irrigate loamy soils at 20–25 centibars. These units require proper installation and regular maintenance. Accuracy may be reduced on soils with high clay content.

Electrical resistance blocks also measure soil water tension in centibars. Compared to tensiometers, they are easier to install. The portable reader and low cost of the units is more conducive to reading soil moisture at several different sites.

Time domain reflectometry (TDR) is a more costly tool for soil water monitoring. It is portable and provides rapid results. These units measure volumetric water content (% VWC). Some units require calibration. Accuracy may be reduced on soils with high clay content. These units will normally last many seasons, although the steel probes do have a tendency to bend if not handled carefully. Damaged probes may affect the accuracy of the TDR.

Capacitance sensors measure the volumetric water content of the soil (mm water/mm soil). Until recently, this technology was used primarily in research trials. Due to decreasing per unit costs, capacitance-based probes are becoming more available for on-farm use.

Capacitance sensors are housed in a waterproof access tube. Multiple sensor points may be fixed along the length of the tube to give readings at different soil depths representative of the crop's rooting zone. The tube is installed at a fixed location in the field, and daily readings are recorded by a data logger or through remote telemetry. A graph is created for each location, allowing the grower to quickly assess water needs. Selecting an appropriate location for the probe

is critical to ensuring the information gathered is representative of the entire field.

For more irrigation information, see:

- *Best Management Practices — Irrigation Management*, Order No. BMP08
- OMAFRA Factsheet, *How to Prepare for Irrigation During Water Shortages*, Order No. 99-023
- OMAFRA Factsheet, *Irrigation Scheduling for Tomatoes — Water Budget Approach*, Order No. 90-049

Fertigation

Fertigation is a method of applying water and nutrients through a drip irrigation system. It can be used to increase the yield and quality of many vegetable crops.

Dissolve a stock solution of soluble fertilizer in a tank and introduce it through a valve into the irrigation system either by suction or pressure. Feed the fertilizer

solution through the system slowly. After the fertilizer has passed through the system, continue to irrigate to flush the lines. **Do not apply phosphorus through the drip tape.** Certain forms of phosphorus will clog the drip emitters. Phosphorous fertilizers encourage the growth of algae in the drip lines. Algae may also cause emitters to plug.

Fertigation applications are usually made weekly. However, depending on the design of the irrigation system, the soil type and time constraints, applications may be made more-or-less frequently. It is important that the irrigation cycle is run for ample time to adequately flush the system after each fertigation. Avoid over-watering after fertigation. Excess water has the potential to leech the fertilizer below the crop rooting zone.

For more information on fertigation, see *Fertigation* on pages 11 and 15, as well as the individual commodity sections of Chapter 9, starting on page 67.

4. Climate and Season Extension

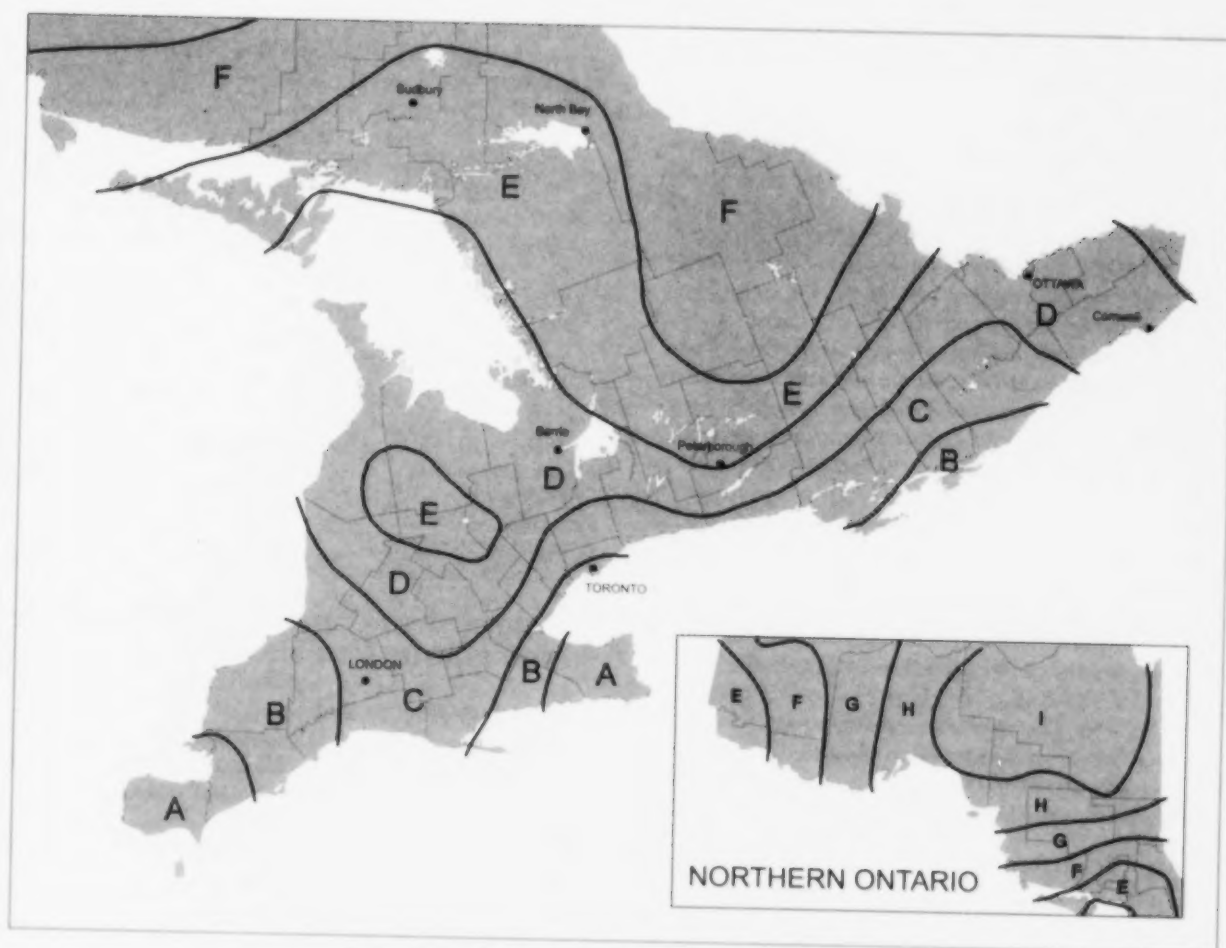


Figure 4-1. Climate Zone Map of Ontario (1976-2005)
Source: Weather Innovations Incorporated

Climate

Most vegetable production is concentrated in Southern Ontario. There are differences in climate even in this small area. The length of the growing season and average temperatures can vary greatly from one area to the next. Vegetable crop development is usually referred to by the number of "days to maturity." This measure indicates the average number of calendar days from planting to harvest maturity. However, due to variability in daily temperatures and light intensity, this measure of "days to maturity" does not always reflect the rate of crop growth under actual growing conditions.

Climate Zones

Figure 4-1, *Climate Zone Map of Ontario (1976-2005)*, this page, shows the Ontario climatic zones based on the average frost-free period. This updated climate zone map of Ontario was created using a larger dataset than the previously published 1961-90 map. As a result, the amended zones reflect a higher degree of accuracy when compared to the previous version.

Table 4–1. Average Frost-Free Period in Climatic Zones of Ontario (1976–2005)

Zone	Frost-Free Period (Average in Days)	Average Date of Last Spring Frost	Average Date of First Fall Frost
A	170–190	April 25	October 20
B	160–170	April 30	October 13
C	150–170	May 3	October 8
D	130–165	May 11	October 1
E	125–145	May 17	September 26
F	115–125	May 24	September 22
G	100–115	May 27	September 17
H	100–110	June 3	September 16
I	90–100	June 7	September 9

Zone A, in Essex and parts of Kent County, has the longest growing season. The growing seasons of the other zones are progressively shorter. The zone lines on the map are approximate and do not represent sharp changes in climate. The length of the growing season and temperatures change gradually from one zone to another.

Table 4–1, *Average Frost-Free Period in Climatic Zones of Ontario (1976–2005)*, this page, gives the average dates of first and last frost (0°C) for each zone.

The dates listed in Table 4–1 indicate that 50% of the time (one year in two) there will be no frost in these locations after that date. There is a 25% risk of a frost occurring 7 days after the listed last spring frost date. Fourteen days after the listed date, the risk decreases to 10%. Conversely, there is a similar risk factor associated with frost occurring before the first fall frost dates.

Note that the frost dates in Table 4–1 refer to the occurrences of 0°C at a standard height of 1.5 m, at which time tender crops will often be damaged. Frost-hardier crops are not usually damaged until temperatures at this height drop below –2°C. The date of occurrence of –2°C is usually about 2 weeks earlier in the spring or later in the fall than the dates mentioned in the table. For a list of vegetable crops and their comparative hardiness, see Table 4–2, *First Field Seeding or Planting Dates for Commercial Production*, this page.

Growing conditions are also influenced by local variations in topography, altitude, natural air drainage and proximity to water. Cold air tends to flow into low-lying areas. Plants at the bottom of a slope are often the first to suffer frost injury. Local variations must be considered in deciding the location and time of planting.

For more information on recommended planting conditions, see Chapter 5, *Seeding and Transplanting*, on page 37.

Table 4–2. First Field Seeding or Planting Dates for Commercial Production

Crops	Zone A	Zone C	Zone E
Frost Hardy			
Asparagus, broccoli, Brussels sprouts, cabbages, lettuce, onions (set, seed, Spanish), radishes, rhubarb, peas, spinach, parsnips, early potatoes	April 1–15	April 15–25	April 25–May 10
Semi-Frost Hardy			
Beets, carrots, cauliflower, celery, late potatoes, early sweet corn	April 15–25	April 25–May 10	May 5–15
Semi-Frost Tender			
Snap beans, sweet corn, tomatoes	May 1–15	May 15–25	May 25–June 5
Frost Tender			
Lima beans, cucumbers, eggplant, muskmelons, peppers, pumpkins, squash, watermelons	May 20–30	May 25–June 5	June 5–15

Temperature Models

Growing Degree Days

Growing degree days (GDDs) are used to estimate the growth, development and maturity of plants and insects during the production season. This system tends to be more accurate than “days to maturity.”

The development of most crops and insects is closely related to the daily accumulation of heat. A certain amount of heat is required to provide enough energy for a plant or insect to move to its next development stage. For example, it takes 300 GDDs for the first emergence of European corn borer moths to occur in Southwestern Ontario. The GDD heat requirements do not change from year to year. But, depending on weather conditions, the amount of actual time (calendar days) can vary between years.

Each species of plant and insect has a minimum base temperature or threshold below which development does not occur. These base temperatures are different for each organism.

To calculate GDD, first determine the mean daily temperature. This is done by taking the maximum and minimum temperatures for the day, adding them together and dividing by two. The base temperature is then

Table 4-3. Insect Growing Degree Days
Base Temperatures

Insect	GDD Base Temp (°C)
General insects	15
Aster leafhopper	9
Cabbage maggot	6
Carrot rust fly	3
Carrot weevil	7
Corn borer	10
Cutworms	7
Onion maggot	4
Tarnished plant bug	9

subtracted from the mean temperature to give a daily GDD. If the resultant daily GDD is a negative number, count it as zero. Each daily GDD is then added up (accumulated) over the growing season.

$$\frac{\text{Daily Maximum Temperature} + \text{Daily Minimum Temperature}}{2} - \text{Base} = \text{Growing Degree Days}$$

GDD models are available for most vegetable crops and several insect pests. See Table 4-3, *Insect Growing Degree Days Base Temperatures*, and Table 4-4, *Vegetable Growing Degree Days Base Temperatures*, this page, for examples of specific GDD base temperatures.

There are four factors to consider when comparing GDD accumulations from various sources or regions.

- **Are the base temperatures used in the equations the same?** Different organisms have different base temperatures used to calculate growing degree days. 150 GDDs at base 10 does not equal 150 GDDs at base 0.
- **Are the start dates for the accumulations the same?** Generally, GDD accumulations start on April 1 each year, but some insect GDD models start at the emergence of a specific life stage. This is referred to as a biofix.
- **Are the equations used to calculate the daily GDDs the same?** Many modifications to the simple GDD calculation have been developed over the years and may still be referred to as degree days.
- **Are the temperatures used in degrees Celsius or Fahrenheit?** GDD accumulations will vary significantly, depending whether they are being tracked in Celsius or Fahrenheit. GDD models have been designed specifically for use in Celsius or in Fahrenheit and cannot be interchanged without making conversions.

Table 4-4. Vegetable Growing Degree Days
Base Temperatures

Base Temperature (°C)					
2.2	4.4	7	10	13	15.5
spinach	asparagus	squash	bean (snap)	cucumber	eggplant
	beet			watermelon	sweet potato
	broccoli				
	carrot				
	lettuce				
	pea				
	potato				

Confusion has been created over the years by the terminology used to describe growing degree days. In Ontario, the terms "growing degree days" (GDDs) and "crop heat units" (CHUs) represent two very different development models. The crop heat units calculation used in Ontario is identical to the traditional corn heat units calculation. Its name was changed to reflect its now broader application to other crops.

Growing degree days are sometimes referred to as "degree days" or "degree days averaging method." Some other jurisdictions use the term "heat units" interchangeably with degree days.

Crop Heat Units (CHUs)

While the principles are similar, the equation for a CHU is more complicated than the equation for a GDD. Crop heat units place limits on maximum and minimum temperatures. Like the base temperature used in GDDs, the limits used in CHUs are determined experimentally and are specific to the crop concerned.

$$\begin{aligned}\text{Daily CHU} &= (Y_{\max} + Y_{\min}) \div 2 \\ Y_{\max} &= [3.33 \times (T_{\max} - 10)] - [0.084 \times (T_{\max} - 10)^2] \\ Y_{\min} &= [1.8 \times (T_{\min} - 4.4)]\end{aligned}$$

- If values are negative, set to 0.
- $T_{\max}$ and $T_{\min}$ = Daily maximum or minimum air temperature in degrees Celsius, usually measured from midnight to midnight.

The calculations for daily minimum and daily maximum temperatures account for important factors in the growth of warm-season crops. Warm-season crops such as corn do not grow in temperatures below 10°C. Corn and other warm-season crops grow faster as the temperature increases up to 30°C. Above 30°C, growth of even warm-season crops slows.

For more information on crop heat units, see the OMAFRA Factsheet, *Crop Heat Units for Corn and Other Warm-Season Crops in Ontario*, Order No. 93-119.

Table 4-5. Plastic Mulch Types

Type	Average Soil Warming at 5 cm (2 in.) depth	Advantages	Disadvantages
Black	2°C–4°C	Prevents weed seed germination.	Soil warming will not occur unless good soil-to-plastic contact is achieved.
Clear	4°C–8°C	Can be used with direct-seeded crops such as sweet corn.	Weed germination may occur under the mulch. Requires good preplant (residual) weed control.
White	–1°C (cools the soil)	Keeps the soil temperature lower to minimize bolting or temperature stress in cool-season crops.	Weed germination may occur under the mulch. Requires good preplant weed control.
White on black	–1°C	Keeps the soil temperature lower to minimize bolting or temperature stress in cool-season crops. Useful when establishing a crop under high temperatures. The black underside prevents weed germination under the mulch.	Usually more expensive than conventional mulches.
Infra-red transmitting (IRT)/thermal photo selective	6°C	Absorbs certain wavelengths of light, preventing weed seed germination and growth.	Expensive. Tomato and pepper yields may be lower on IRT mulches than on black.
Photo-degradable	Same as undegradable mulch	Breaks down with exposure to sunlight, eliminating the need for retrieval and disposal at the end of the season.	Rate of breakdown can be inconsistent. Buried edges frequently do not break down, leaving plastic residue in the field. These plastic residues are often difficult to retrieve.
Biodegradable	Same as undegradable mulch	Usually a starch-based plastic. Broken down by soil micro-organisms.	Most of these mulches are relatively new and only limited quantities are available. There is a wide range in the quality and degradability of products. Always field-test new products on a limited scale before making a large investment.

Season Extension

Many vegetable crops, especially heat-loving crops such as cucurbits (vine crops), peppers, tomatoes, eggplant and sweet corn, benefit from the use of plastic mulch and row covers. Some benefits associated with season extension include:

- earlier harvest
- increased yield
- higher-quality produce
- soil moisture retention
- reduced disease pressure
- reduced fertilizer leaching
- increased season-long nutrient availability
- weed control

Plastic Mulch

Most mulches are made of polyethylene. Table 4-5, *Plastic Mulch Types*, this page, describes the different types. They are available in widths of 1.2–1.5 m with a thickness of 1–1.5 mil (thousandths of an inch).

Black plastic mulch is usually available in either a smooth or embossed texture. Embossed films tend to stretch more, offering a tighter fit to the soil bed.

Mulch-laying equipment is readily available. Several commercial plastic mulch layers are available. Proper set-up and maintenance of this equipment is essential. The edges of the mulch should be well covered, and the plastic should be tight on the soil surface to permit heat transfer to the soil. Angle the discs and press wheels of the mulch layer to ensure a tight and uniform fit.

Do not lay mulch on dry soil. If the soil is very dry, irrigate or wait for rainfall before laying. Soil moisture is important for heat retention. Lay mulch 2–3 weeks prior to planting for maximum soil heating.

Row Covers

Row covers can be used to promote earlier production by increasing the canopy air temperature and protecting young transplants from wind damage. There are two basic types: floating row covers and low tunnels.

Regardless of the type of row cover used, heat can build up inside the covers and damage crops. Temperatures should be monitored. Remove or ventilate the covers when the temperature exceeds 32°C–35°C. For crops

that require bee pollination (vine crops), remove or open up row covers at flowering time.

High temperatures under the row cover during flowering may cause fruit deformities or a decrease in pollen viability.

Floating Covers

Floating covers are made of polypropylene or various polyester-type fabrics and are laid directly over the crop. They are available in sheets up to 15 m wide to cover multiple rows. Floating covers are well suited for large acreages and low-growing plants. They are not recommended for use on upright-growing crops such as tomatoes and peppers. They may cause abrasions on the plant's shoot tips.

Low Tunnels

Low tunnels are made of white or clear polyethylene and are supported over the crop on wire hoops. The plastic usually has slits or perforations for ventilation. Commercially available equipment installs hoops, lays the plastic covers over the hoops and buries the edges of the row cover in one operation.

Research in Ontario has demonstrated that use of low tunnels can result in earlier production of lettuce, peppers, cucumbers and melons. Remove tunnels used on fruiting vegetables such as tomatoes, cantaloupe and watermelon well before flowering. Extended use of row covers on tomatoes may result in reduced fruit set.

High Tunnels

A high tunnel is a semi-permanent, simplified greenhouse. It is typically made of a metal tubing framework and a single sheet of polyethylene plastic. Each end of the tunnel is open or contains a large wooden door frame, allowing for the use of small field equipment inside the tunnel.

A high tunnel may expand the growing season by 3–4 weeks, but will not function well for production during the winter. It is possible to expand the growing season even more by adding temporary heaters to the structure.

In addition to expanding the growing season, high tunnels may improve the harvest quality of certain vegetable crops. Shoulder-checking (russetting) and cracking of tomatoes may be reduced when the fruit is protected from rain. A reduction in leaf wetness may also help reduce disease problems.

During the hot summer months, the tunnels may be ventilated simply by rolling up the plastic sidewalls, allowing air to move through the structure. As the inside of the tunnels does not receive any natural rainwater, drip irrigation is highly recommended.

Remove the plastic from the high tunnel during the winter months. This will improve the lifespan of the plastic. It will also prevent structural damage to the tunnel due to snow load or inclement weather.

Plastic Disposal

Used plastic mulches are difficult to recycle due to the amount of dirt, plant material and water present. Limited recycling opportunities exist in some areas. In most areas, disposal at a licensed landfill site is currently the most practical option. Burning or on-farm burial is not recommended.

5. Seeding and Transplanting

Plant Populations

Each crop should be spaced according to its optimum needs. The distance between rows will also be determined by the methods used to cultivate, plant and harvest the crop. Specific spacing recommendations can be found for each individual commodity in Chapter 9, starting on page 67.

For average plant populations at various row spacings, see Table 5-1, *Plant Populations at Various Planting Distances*, this page.

Table 5-1. Plant Populations at Various Planting Distances

Row Spacing (in.)	per acre									
	Distance within the Row (in.)									
	4	6	12	18	24	30	36	48	60	96
12	130,680	87,120	43,560							
18	87,120	58,080	29,040	19,360						
24	65,340	43,560	21,780	14,520	10,890					
30	52,272	34,848	17,424	11,616	8,712	6,970				
36	43,560	29,040	14,520	9,680	7,260	5,808	4,840			
44	35,640	23,760	11,880	7,920	5,940	4,752	3,960	2,970		
48	32,670	21,780	10,890	7,260	5,445	4,356	3,630	2,723		
60			8,712	5,808	4,356	3,485	2,904	2,178	1,742	
96			5,445	3,630	2,723	2,178	1,815	1,361	1,089	681
120					2,178	1,742	1,452	1,089	871	545

Row Spacing (cm)	per hectare									
	Distance within the Row (cm)									
	10	15	30	45	60	75	90	120	150	240
30	333,333	222,222	111,111							
45	222,222	148,148	74,074	49,383						
60	166,667	111,111	55,556	37,037	27,778					
75	133,333	88,889	44,444	29,630	22,222	17,778				
90	111,111	74,074	37,037	24,691	18,519	14,815	12,346	9,259		
110	90,909	60,606	30,303	20,202	15,152	12,121	10,101	7,576		
120	83,333	55,556	27,778	18,519	13,889	11,111	9,259	6,944		
150			22,222	14,815	11,111	8,889	7,407	5,556	4,444	
240			13,889	9,259	6,944	5,556	4,630	3,472	2,778	1,736
300					5,556	4,444	3,704	2,778	2,222	1,389

Table 5–2. Row Length per Acre or per Hectare at Various Row Spacings

Distance Between Rows		Length of Row	
Imperial	Metric	Feet of Row/ Acre	Metres of Row/ Hectare
6 in.	15 cm	87,120	66,667
12 in.	30 cm	43,560	33,333
18 in.	46 cm	29,040	21,739
20 in.	51 cm	26,136	19,608
24 in.	62 cm	21,780	16,129
30 in.	76 cm	17,424	13,158
36 in.	91 cm	14,520	10,989
40 in.	100 cm	13,068	10,000
42 in.	110 cm	12,445	9,091
48 in.	120 cm	10,890	8,333
60 in.	150 cm	8,712	6,667
72 in.	180 cm	7,260	5,556
84 in.	210 cm	6,223	4,762
96 in.	240 cm	5,445	4,167
108 in.	270 cm	4,840	3,704
120 in.	300 cm	4,356	3,333

Table 5–2, *Row Length per Acre or per Hectare at Various Row Spacings*, this page, shows the row length per acre (or hectare) at various row spacings.

Seeding

Use only high-quality seed that is certified disease-free. In most vegetable crops, seed treatments are recommended to protect against early-season insects and diseases. Registered seed treatments are listed in the individual crop sections in Chapter 9, *Crop Management Recommendations*, starting on page 67.

Saving seed from previous crops is not recommended. Saved seed has a high potential for disease contamination, and seed harvested from hybrid cultivars will not grow true to type. Common vegetable diseases that may be transmitted by infected seed include late blight in potatoes, as well as gummy stem blight in cucurbits and anthracnose in beans. Many of the viruses infecting vegetables are also seed borne.

Pelletized seed has been coated to make it larger or more uniform. Onion, carrot and lettuce seed tends to be irregularly shaped or small. Pelletized seed makes the mechanical planting of these crops much easier.

Table 5–3. Minimum Soil Temperatures for Vegetable Seed Germination

Vegetable	°C	Vegetable	°C
asparagus	10	okra	16
bean	16	onion	2
bean, lima	16	parsley	4
beet	4	parsnip	2
cabbage	4	pea	4
carrot	4	pepper	16
cauliflower	4	pumpkin	16
celery	4	radish	4
chard, swiss	4	spinach	2
corn	10	squash	16
cucumber	16	tomato	10
eggplant	16	turnip	4
lettuce	2	watermelon	16
muskmelon	16		

Primed seed has been partially hydrated, then dried down. This treatment results in earlier germination and better uniformity over a greater range of soil moisture and temperature conditions.

Most seeds are relatively tough; however, the seeds of bean, pea and sweet corn (especially the supersweet varieties) are fragile. Cracked or shattered seed coats may reduce germination and establishment. Take care to avoid damage during handling.

Soil Temperature

Soil temperature has a large impact on the early-season growth and development of a crop. Seeds planted into cold soils may be damaged by low temperatures. This can delay germination and stand establishment, reducing yield potential. Acceptable soil temperatures vary greatly between vegetable crops. See Table 5–3, *Minimum Soil Temperatures for Vegetable Seed Germination*, this page.

Planting Depth

Achieving the appropriate planting depth is a critical component of crop establishment and early-season growth. Improper seed placement often results in a reduced stand and lower yields. Seeds planted too close to the surface may not receive enough soil moisture to germinate and often fall prey to seed predators. Seeds planted unnecessarily deep will be slow to emerge, especially in cold soils.

Table 5-4. Field Seeding Depth¹ and Seeds per Gram

Crop	Seeds (per g)	Planting Depth	
		(mm)	(in.)
Asparagus	50	25	1
Beans, snap	2-3	40	1½
Beans, lima	1-3	40	1½
Beets, Swiss chard	50	15	½
Brassica crops - seeded	280-350	5	¼
Brassica crops - transplants	280-350	76-100	3-4
Carrots	900	5	¼
Celery, celeriac	1,800	3	¼
Chicory	600	5	¼
Collard	280	5	¼
Corn	4-8	25-65	1-2½
Cucumbers	40	20	¼
Eggplant - transplant	200	76-100	3-4
Endive	500	5	¼
Kale	270	5	¼
Kohlrabi	280	5	¼
Leeks	350	15	½
Lettuce	700	5	¼
Melons	40	25	1
Mustard - transplant	550	76-100	3-4
Onions	280	15	½
Parsley	550	5	¼
Parsnips	200	15	½
Peas	3-6	25	1
Peppers - transplant	150	76-100	3-4
Pumpkins - seeded	4	25	1
Pumpkins - transplant	4	76-100	3-4
Radishes	125	15	½
Rutabagas	280	5	¼
Spinach	90	20	¼
Squash - seeded	10	25	1
Squash - transplant	10	76-100	3-4
Tomatoes - transplant	350	76-100	3-4
Watermelons - transplant	10	76-100	3-4

¹ The planting depths listed here are for field placement. See Table 5-8, *Vegetable Transplant Requirements*, on page 41, for transplant production recommendations.

Slow-emerging plants are more susceptible to seed decay or seed insects, such as the wireworm or seed corn maggot. Table 5-4, *Field Seeding Depth and Seeds per Gram*, this page, outlines the approximate planting depth and number of seeds per gram for each vegetable crop.

Table 5-5. Vegetable Seed Life Expectancy

1 to 2 Years	3 to 4 Years		5+ Years
Corn	Asparagus	Fennel	Cucumbers
Leeks	Beans	Kale	Endive
Okra	Beets	Mustard	Lettuce
Onions	Broccoli	Peas	Muskmelons
Parsley	Brussels sprouts	Pumpkins	Radishes
Parsnips	Cabbages	Rutabagas	
Peppers	Carrots	Spinach	
Rhubarb	Cauliflower	Squash	
	Celery	Tomatoes	
	Chinese cabbage	Turnips	
	Eggplant	Watermelons	

Seed Storage

Germination and vigour of all seed declines over time. Seed storage temperatures of 5°C–10°C and 40%–50% relative humidity are ideal. Excessively low humidity may result in poor germination rates. High humidity will increase the moisture content of the seed and reduce viability. It will also increase the likelihood of fungal contamination.

Store seed in waterproof, vapour-proof containers. Keep in mind that seed vigour declines more rapidly than germination. Old seed may still germinate, but the seedlings will be weaker, slow to establish and more prone to disease. Even under good storage conditions, life expectancy varies between different types of vegetable seed. See Table 5-5, *Vegetable Seed Life Expectancy*, this page.

Transplanting

For many vegetable crops in Ontario, transplanting offers a number of advantages over direct seeding. Transplanted crops mature faster, giving growers access to early markets. Long-season vegetable crops such as tomatoes, peppers, eggplant and melons usually yield significantly more when they are transplanted.

Transplants are also quick to establish a canopy in the field, giving plants a valuable head start on the weeds. This is particularly important in crops where weed control options are limited.

Not all vegetable crops are well suited to transplanting. The level of management required for successful transplant production varies with crop type. See Table 5-6, *Relative Ease of Transplanting Vegetables*, next page.

Table 5–6. Relative Ease of Transplanting Vegetables

Crop	Characteristics
Easy	
Beets, broccoli, cabbages, Brussels sprouts, chard, lettuce, tomatoes	Efficient in water absorption; rapid formation of new roots.
Moderate	
Eggplant, leeks, onions, peppers, celery, cauliflower	Young plants do not absorb water as efficiently, but new roots form quickly.
Difficult	
Muskmelons, watermelons, cucumbers, squash, sweet corn	Root system is easily injured during transplanting and resumes growth slowly; require special care.

Trays

Most commercial vegetable transplants are grown in plastic trays, usually in the range of 30–288 cells per tray. Various types and sizes are available. For recommended tray sizes, see Table 5–7, *Suitable Tray Sizes for Various Vegetable Species*, this page.

In general, larger cells are used for early crops. They produce a bigger, more mature transplant, resulting in earlier yields. They are also more expensive to produce. Smaller cells are used for mid-to-late-season crops. They are cheaper to produce, but smaller cell volume makes water and nutrient management critical.

Tray Disinfection

For transplants grown under contract, the terms may specify that new trays be used for each crop. In other cases, growers may choose to use trays for more than one season. Trays must be thoroughly sanitized before being reused. They must also be structurally and chemically able to withstand both the disinfection treatment and another season of handling.

There are two effective ways to sanitize used trays:

Solarization: Wash, stack and cover trays with cloth or plastic. Leave them in the greenhouse during the summer. The heat will dry disease organisms. Use square-celled trays, to minimize the amount of growing media left in the trays from the previous use.

Chemical Disinfectants: Wash trays individually to remove particles of growing media. After washing, dip or spray them with a disinfectant, according to manufacturer's recommendations. Chlorine bleach can also be used. Dipping bulk lots of trays into a cleaning solution has not proven successful. **Caution:** Bleach residues on the trays can damage the seedlings. Rinse trays thoroughly after disinfecting with bleach.

Table 5–7. Suitable Tray Sizes for Various Vegetable Species

Crop	Tray Size	Cells /ft ²	Cells /m ²	Production Notes
Early-market tomatoes	24	14	151	Usually seeded in 288s or 406s and transplanted to large tray at first true leaf.
	38	23	248	
	50	31	334	
Mid-to-late-season tomatoes	128	78	840	Direct seeded in tray.
	288	175	1,884	
Processing tomatoes	200	122	1,313	According to processor specifications.
	288	175	1,884	
	406			
Early peppers	50	31	334	Transplant seedlings or direct seed in tray.
	72	47	506	
Mid-to-late-season peppers	128	78	840	Direct seed in tray.
	200	122	1,313	
Early brassica crops	72	47	506	Direct seed in tray.
	98			
Mid-to-late-season brassica crops	128	78	840	Direct seed in tray.
	200	122	1,313	
Cucumbers, melons, squash	24	14	151	Direct seed in tray. Do not allow plants to elongate in the greenhouse.
	128	78	840	
Cooking onions	200	122	1,313	Direct seed in tray; seedlings should be clipped several times to produce a stocky transplant.
	288	175	1,884	
	338			

Growing Media

The ideal pH range for growing media is 6–6.8. Growing media must be:

- sterile (free of insects, pathogens, nematodes, weed seeds)
- uniform
- well-drained
- lightweight
- convenient for storage and handling
- non-crusting
- able to hold water well
- free of large pieces of bark or twigs

Many commercially prepared soil-less mixtures meet these criteria. The commercial mixtures generally contain peat moss, perlite, vermiculite and a wetting agent. Some also contain fertilizer (nutrient charge). The fertilizer content of different mixtures may vary greatly. To manage the fertilizer program, you must know the nutrient content of the growing media. Avoid mixtures containing slow-release fertilizer or high nutrient charges; they can restrict the flexibility of a fertilizer program.

Table 5-8. Vegetable Transplant Requirements

Vegetable	Seed Required for 10,000 Transplants g (oz)	Seeding Depth cm (in.)	Germination Temperature °C ¹			Days to Germination ²	Optimum Growing Temperature °C		pH Tolerance	Time (weeks)
			Min.	Opt.	Max.		Day	Night		
Broccoli	57 (2)	0.6 (¼)		29		4	16-21	10-16	6.0-6.8	4-7
Brussels sprouts	57 (2)	0.6 (¼)		27		5	16-21	10-16	5.5-6.8	4-7
Cabbages	57 (2)	0.6 (¼)	7	29	35	4	16-21	10-16	6.0-6.8	4-7
Cauliflower	57 (2)	0.6 (¼)	7	27	29	5	16-21	10-16	6.0-6.8	4-7
Celery ³	28 (1)	0.15-0.3 (⅛-¼)	16	21	21	7	18-24	16-18	6.0-6.8	10-12
Cucumbers	567 (20)	1.3 (½)	16	35	35	3	21-24	16-18	5.5-6.8	2-4
Eggplant	113 (4)	0.6 (¼)	24	29	32	5	21-27	18-21	5.5-6.8	5-7
Lettuce	28 (1)	0.3 (⅛)	4.5	24	27	2	13-18	10-13	6.0-6.8	4
Muskmelons	567 (20)	1.3 (½)	24	32	35	3	21-24	16-18	6.0-6.8	3-5
Onions	85 (3)	0.6 (¼)	10	24	35	4	16-18	8-15	5.5-6.8	8-12
Peppers	198 (7)	0.6 (¼)	18	29	35	8	18-24	15-18	5.5-6.8	5-9
Squash	1,475 (52)	1.3-1.9 (½-¾)	21	35	35	3	21-24	16-18	5.5-6.8	2-4
Tomatoes	85 (3)	0.6 (¼)	16	29	29	5	18-24	15-18	5.5-6.8	5-8
Watermelons	1,475 (52)	1.3-1.9 (½-¾)	21	35	35	3	21-27	18-21	5.0-6.8	2-4

¹ Germination may be possible for many vegetables at lower or higher temperatures, but percentage, speed and uniformity of germination will suffer.

² Under optimum germination temperatures. Primed seed will germinate faster than unprimed seed under most conditions.

³ Daily fluctuation to 16°C (61°F) or lower at night is essential.

Seeding and Germination

Vegetable transplants are generally sown one seed per cell, usually at a depth of about twice their diameter. See Table 5-8, *Vegetable Transplant Requirements*, this page, for information on seeding depth, temperature, pH and time required for producing various types of vegetable transplants.

Obtain rapid, uniform germination by:

- watering trays with warm water (27°C–28°C) immediately after seeding
- placing trays in a germination chamber, maintained at the optimum temperature and humidity for that crop
- moving trays out of the germination chamber as soon as the seed coat has cracked and the root begins to emerge, but before the shoot emerges.

Transplant Growth and Development

It is difficult to raise multiple crops within the same greenhouse if they have different environmental requirements (temperature, ventilation, light, water, fertility). If possible, grow crops with dissimilar requirements in different areas of the greenhouse where they can be managed as required.

For the best quality transplants, manage the environment to achieve slow, continuous growth from germination to field-readiness. Avoid large fluctuations in temperature, water and fertility.

Temperature

Vegetable crops vary in their response to temperature. The optimum day and night growing temperatures for a number of crops are listed in Table 5-8, *Vegetable Transplant Requirements*, this page.

Table 5–9. Acceptable Ranges of Water Quality and Correction Methods

Factor	Range	Correction
pH	5.5–6.5	Acid can be used to lower the pH.
Bicarbonate level	60–100 ppm	Acid can be used to lower the bicarbonate reading. For each 60 ppm of bicarbonate above this range, add 7 L of phosphoric acid (85%) ¹ or nitric acid (67%) ² per 100,000 L of water. For example, a bicarbonate level of 220 ppm would require 14 L of acid to correct the problem.
EC (Electrical conductivity)	<0.6 mmho/cm in straight water 1.0–2.0 mmho/cm with fertilizer added	The fertilizer program can be adjusted to maintain a safe EC.
Nitrate levels	Normally less than 20 ppm	Adjust the fertilizer program accordingly.
Sulfates	Normally 150–250 ppm	
Chlorides	Normally 20–400 ppm	

¹ Use no more than 7 L of phosphoric acid per 100,000 L of water to avoid crop problems (stretching). Use nitric acid for neutralizing more than 60 ppm bicarbonate.

² Each 7 L of nitric acid will contribute 14 ppm of nitrate nitrogen to the irrigation water. Adjust the nitrogen fertilizer rate accordingly.

Warm-season vegetable crops such as tomatoes, peppers, eggplant and cucurbit crops are susceptible to chilling injury when transplants are exposed to temperatures above freezing, but below 10°C for an extended period of time. Chilling causes stunting of growth and can have long-lasting effects on field establishment and fruit set.

Height Control

Excessive stem elongation can be caused by low light conditions as well as excessive heat, fertilizer or water. “Pillowing” is uneven growth that results from differences in air circulation and watering between cells within trays.

Control plant height by managing the day/night temperature fluctuations in the greenhouse. Night temperatures that exceed day temperatures reduce stem elongation. Adjusting morning temperatures to 4°C–5°C lower than the night-time temperature will give good height control. Avoid chilling temperatures with warm-season vegetable crops.

Restricting phosphate can also effectively restrain transplant growth in the greenhouse. However, excessive phosphate reductions may result in slower field establishment after transplanting.

Watering

Plug transplants should be watered thoroughly in the morning and “spot-watered” as necessary in the afternoon. Avoid watering late in the day. Disease problems increase when plants remain wet overnight. Disease organisms can be present in surface or wellwater sources. Use treated water if possible.

Water should be in the 15°C–20°C range to prevent shocking the plants.

The amount and frequency of watering will vary depending on cell type, growing media, greenhouse ventilation and weather conditions. Water thoroughly

and moisten the entire plug to promote root growth to the bottom of the plug. Allow the plug to dry down before watering, but do not let the plant wilt.

Water Quality

Submit a water sample to an accredited lab for analysis prior to the growing season. The greenhouse fertilizer program may have to be adjusted according to the pH, bicarbonate level and nutrient content of the water supply. See Table 5–9, *Acceptable Ranges of Water Quality and Correction Methods*, this page.

Transplant Fertility

Vegetable transplants are usually fertilized with soluble fertilizer, applied in the irrigation water. See Table 5–10, *Analysis for Various Soluble Fertilizers*, opposite page, for a list of fertilizers commonly used in transplant production. Use fertilizers that supply most of the nitrogen in nitrate form. Avoid fertilizers with a high concentration of urea.

A high concentration of phosphate (P_2O_5) may promote excessive stem elongation. Use a fertilizer with a low-to-medium phosphate concentration, or use a fertilizer with no phosphate for most feedings and apply a high-phosphate fertilizer once every four or five feedings to promote growth. Do not withhold phosphate completely, as this will delay field establishment.

Vegetable crops vary in their response to fertilizer. The feeding program must be designed for each crop. Adjust the fertilizer program based on the nutrient content of the growing media, the water analysis and the cell size (larger cells require less fertilizer). See Table 5–11, *Vegetable Transplants Fertility Guidelines*, opposite page.

Table 5-10. Analysis for Various Soluble Fertilizers

Fertilizer Analysis	Rate for 100 ppm N (g/100 L of water)	Parts per Million			EC mmho/cm ¹
		N	P	K	
20-20-20	50	100	43	83	0.40
20-10-20	50	100	21	83	0.60
20-8-20	50	100	17	83	0.75
17-5-19	59	100	12	92	1.00
15-5-15	67	100	14	83	0.70
14-0-14	71	100	0	83	0.85

¹ Electrical conductivity of a 100 ppm solution in micromhos. The EC values were determined with a conductivity meter using distilled water. The EC values obtained will vary depending on the background EC of the water source.

Toxicities and Deficiencies

Nutrient deficiencies are more common than nutrient toxicities. Many growers are very cautious about overfertilizing for fear of "burning" the roots or stems.

Phosphorous-deficient transplants show very definite purple colouration along the stem and underside of leaves. Plants that have too little nitrogen will have pale-green foliage. Too much nitrogen will result in very white stems and dark-green leaves. For more information, see Chapter 1, *Vegetable Crop Fertility*.

Soluble salts in the fertilizer water may prevent germination or damage the young seedlings. On older seedlings, salt-injured plants are often stunted and dark green. Burning of the leaf margins and tan coloured roots are other common symptoms of salt injury. Salts are measured by the electrical conductivity (EC) of the water. Table 5-9, *Acceptable Ranges of Water Quality and Correction Methods*, opposite page, lists a range of acceptable EC levels.

Hardening-Off

It is important to prepare transplants for the harsher environment of the field by hardening them off. This is especially important for early-season plantings.

Reduce greenhouse temperatures to harden-off transplants. Warm-season crops should not be hardened at temperatures below 13°C. Cool-season crops can be hardened at lower temperatures. Certain brassica crops can be susceptible to "bolting" or "buttoning" in the field if the transplants are exposed to prolonged temperatures below 10°C.

Slightly reduce water, as part of the hardening process. Do not let plants wilt excessively. They must be actively growing for good field establishment. Increasing air movement around the transplants also assists in the hardening process.

Table 5-11. Vegetable Transplants Fertility Guidelines

Crop	Fertility Guidelines
Tomatoes	Very responsive to fertilizer, excess fertility will reduce transplant quality. If feeding at every watering, use a fertilizer concentration of 50–100 ppm N, depending on the stage of development. There may be some advantage to feeding less often at a higher concentration.
Peppers	Require more fertilizer than tomatoes. If feeding at every watering, use approximately 100 ppm N; increase the concentration if feeding less often.
Onions	Require moderate fertility. Apply 100–200 ppm N weekly. Fertilize less frequently under cool, cloudy conditions.
Brassica crops	Do not require as much fertilizer as other crops. One application per week of 100–150 ppm N should be sufficient under most conditions.
Vine crops	Have a relatively short growing cycle compared to other transplant crops. Use 100–150 ppm N at weekly intervals for a total of 2–4 applications.

If there is no risk of frost, consider holding plants outside for several days before field planting. This allows them to become accustomed to field conditions while still in trays. Select a location that is exposed to full sunlight but is protected from drying winds. Check plants regularly and water as required.

Do not harden off plants by withholding fertilizer, as this can result in nutrient deficiencies and delay field establishment. Slow-to-establish plants are more susceptible to insects, diseases and poor growing conditions.

Storage of Plug Transplants

If properly stored, tomato transplants can be held for up to 2 weeks with little reduction in plant stand or vigour. Either return them to the greenhouse or store them outside. Storage in an enclosed trailer or barn for more than 1 or 2 days will result in very soft, elongated plants.

During storage:

- Elevate the racks to prevent root growth through the bottom of the plugs.
- Bring the plants inside if there is a risk of frost.
- Fertilize if planting is delayed by more than 5–7 days. A low-phosphorus, soluble fertilizer such as 20-8-20 or 20-10-20, applied in the irrigation water according to manufacturers directions, is suitable for this purpose.

Disease and Insect Management

The primary means of controlling diseases on vegetable transplants are by seed treatment, sanitation and by managing the greenhouse environment to suppress disease development.

Seed treatment with hot water, acid or chlorine may help reduce bacterial and fungal pathogens on the seed. Acid and chlorine disinfection is very difficult to do on-farm. Seed can be damaged if protocols are not followed exactly. In most circumstances, growers must trust their seed supplier to perform the seed disinfection effectively. For more information on seed treatment methods, see the OMAFRA Factsheet, *Bacterial Diseases of Tomato*, Order No. 05-069. Do not apply hot-water, acid or chlorine treatments to pre-treated vegetable seed.

Using fungicide-treated seed will help prevent seed decay and damping-off. See the individual commodity sections, starting on page 67, for a list of recommended seed treatments.

Certain transplant or greenhouse crops should not be raised in close proximity, as one may act as a source of disease or as an alternate host for insect vectors. Avoid growing tomato transplants close to greenhouses used for flowers or greenhouse cucumbers. Pepper and tomato transplants should not be raised in the same greenhouse complex.

Insects such as aphids and thrips may transmit disease into and within the greenhouse. Fungus gnat and shore fly larvae can cause damage by feeding on seedling roots and by spreading damping-off organisms.

Monitor for thrips and aphids. Hang blue sticky traps close to the seedling canopy. Indicator plants (such as potted petunia for tomato spotted wilt virus) can be placed at the ends of the greenhouse.

For more information on managing insects and diseases on transplants, see the individual commodity sections in Chapter 9, starting on page 67.

Never produce field transplants in the same greenhouse as a commercial greenhouse vegetable (i.e., greenhouse tomatoes, peppers and cucumbers). Diseases and insects from the mature crop can easily infect young seedlings, potentially introducing new pests into the field.

Greenhouse Sanitation

Sanitation is an important component of insect and disease control. Dirt and residue left from the previous crop may harbour pests. This increases the risk of an outbreak occurring in the next crop. Thoroughly clean, wash and disinfect the greenhouse, all work surfaces and equipment after every crop. For more information see *Storage Sanitation*, on page 50.

Herbicide Injury

Equip greenhouses with a sprayer dedicated to herbicides only and a separate sprayer for fungicides and insecticides. Contamination may cause serious damage to greenhouse plants.

Avoid spraying weeds outside the greenhouse during the growing season. Herbicide mist or fumes may drift or be drawn into the greenhouse. Transplant trays left outside may be inadvertently sprayed. Trays stored near herbicides can also absorb fumes. Once contaminated, trays cannot be cleaned effectively.

6. Food Safety and Storage

On-Farm Food Safety

Ontario growers take pride in producing safe and wholesome fruit and vegetables. On-farm food safety and traceability programs demonstrate to buyers that food is grown with quality and safety in mind.

Food Safety Hazards

A hazard is any agent associated with food that has the potential to cause an adverse health effect. These hazards include biological, chemical and physical food contaminants.

Biological Hazards

Microorganisms such as bacteria, viruses and parasites present the greatest food hazard risk when fruit and vegetables are consumed raw. Some microbes that have been associated with fruit and vegetable outbreaks in the past include *E. coli* 0157:H7, salmonella, hepatitis A and cryptosporidium.

Chemical Hazards

Chemical hazards include pesticide residues on produce that exceed the maximum residue limits, contamination from disinfectants, hydraulic fluids or other chemicals used on the farm, or pollutants found in soil such as trace metals or persistent organic pollutants. All chemical products used during the production, handling or preparation of food must be used according to government regulations and manufacturer's labelled instructions.

Allergens are chemical hazards due to the presence of allergenic agents. Some individuals may have an allergic response to natural or foreign chemicals present in food. The most common allergic reactions are caused by nuts, sesame seeds, dairy products, eggs, fish, shellfish, soy, wheat and sulphites. Allergenic agents may occur naturally or be introduced through cross-contamination during handling and packaging.

Physical Hazards

Physical hazards include any foreign object (metal, wood, stones, glass) from the environment or equipment that could end up in fruit and vegetables. These objects could come from machinery, harvesting and packing equipment, hunters (e.g., shotgun casings), broken containers, etc.

For more information, see the OMAFRA Factsheet, *Managing Risk on Farms Open to the Public*, Order No. 06-087.

Good Agricultural Practices

Be aware of the risks and address potential problems before they occur to help ensure the production of safe food. Many of the good production practices for food safety also complement existing agricultural best management practices. These practices will help reduce post-harvest losses, while maintaining high-quality production in a sustainable environment.

In fruit and vegetable production, good production practices are aimed at reducing risks associated with the use of pest control products, manure and water.

Pest Control Products

When using a pest control product, take the time to read the label and follow all label directions. Apply the correct rate of product, and follow the pre-harvest intervals. Calibrate sprayers regularly. Keep accurate pesticide and weather records.

Manure and Compost

Manure and compost provide valuable nutrients and benefits to the soil. However, manure and improperly managed compost can be a potential source of pathogen contamination. If compost is used, be familiar with proper compost management for pathogen reduction. If you purchase manure or compost, ask questions about the composting process or get a certificate of analysis for the product. If you produce compost, document the process.

Incorporate manure into the soil immediately after application. Maximize the time between application and harvest to ensure that the manure has fully broken down in the soil before the crop is harvested. It is a good practice to allow at least 120 days between the application of manure and harvest of fresh market vegetable crops. Be aware of the potential for contamination of crops by windblown debris from feedlots and manure storages. Do not allow runoff from barnyards or manure storages to contaminate the field or the packing area.

For more information, see the OMAFRA Factsheets:

- *Manure Composting as a Pathogen Reduction Strategy*, Order No. 05-021
- *Agricultural Composting Basics*, Order No. 05-023

Table 6-1. Variability of Water Quality

Water Source Type	Quality Variability
River or stream	High
Pond filled by stream, ditch or runoff	High
Lake	Medium
Pond filled by groundwater, spring or well	Medium
Well supplying directly to irrigation system	Low
Municipal water source	Low

Water

In fruit and vegetable production, water is frequently used for irrigation, evaporative cooling, frost protection, packing and washing. When assessing water usage on the farm, consider the source of the water, when and how the water is used, and the type of produce.

How the water looks or smells is not a reliable indicator of its safety. For produce cooling, washing and packing, use water that meets drinking water quality standards. Test wash water sources for contaminants on a periodic basis. Many growers choose to chlorinate wash water to further reduce the risk of contamination. See *Washwater Sanitation*, on page 50.

Table 6-1, *Variability of Water Quality*, this page, describes the level of variability typically associated with each water source.

Worker Health and Hygiene

Harmful microbes are spread on hands and gloves or through coughing or sneezing. Pay attention to the personal hygiene and health of field and packing-house workers:

- Provide worker training on hand washing and personal hygiene.
- Keep toilets and hand-washing facilities clean and well stocked.
- Locate toilets in close proximity to the workers but not in an area where waste water run-off from the hand-washing facilities could contaminate the field.
- Develop a system to report any injuries or illnesses that could increase the risk of contamination.

Food Safety Programs and Certification

There are a number of food safety assurance programs available to growers. The food safety program a producer chooses will depend upon a number of factors, including ease of implementation, cost and what the buyer requests. Certification programs usually require a self-inspection using a prepared checklist followed by an external or third-party audit.

Canadian Programs

Developed by national producer organizations, these voluntary on-farm food safety programs are being implemented across the country. The Canadian Horticultural Council has developed on-farm food safety programs for fruit and vegetable growers. For more information, see the Canada Horticultural Council website at www.hortcouncil.ca/OFFSMnls.htm.

OMAFRA has developed a program suitable for all commodities called Advantage Good Agricultural Practices. It is available on the OMAFRA website along with staff training tools for personal hygiene. Buyers may dictate what food safety measures or programs are required.

Traceability

Traceability is the ability to trace product from the field to the consumer. Producers have a number of reasons to keep records tracking the production and distribution of their product.

By itself, traceability will not produce a safer product; however, it can help to quickly identify the source of a problem and allow the producer to resolve it faster. Traceability can also be part of marketing foods. A thorough record-keeping system can verify attributes such as organic, country-of-origin, earth-friendly and fair trade.

Biosecurity

Biosecurity is the protection of Canada's economy, environment and society from pests and disease. It includes preventing the introduction of new pests and diseases and eradicating or effectively managing the spread of those that have already arrived. As a producer, taking common sense precautions to prevent disease from coming onto the farm is a worthwhile investment. Some precautionary protocols include purchasing plant stock and seed from known, reputable sources.

Cooling and Storage

Cooling

Rapid and efficient cooling is the most effective management practice for maintaining the quality and shelf-life of fresh vegetables. It is essential that only good quality produce is placed in cold storage. There are several cooling methods available for different sizes of operations and types of crops being grown. Table 6-2, *Vegetable Cooling Methods*, this page, lists the suggested cooling methods for many vegetable crops.

Room Cooling

Containers of produce are placed into a refrigerated room and cold air from the evaporator coils slowly cools the product. It takes considerable time to cool produce to acceptable storage temperatures. The cold air does not always penetrate deep within the container. Highly perishable produce may suffer significant quality loss and hence shelf-life.

Forced-Air Cooling

Vegetables are placed in a refrigerated room, and cold air is pulled through the containers using high-capacity fans. An effectively designed system allows good contact between the cold air and the produce. Forced-air cooling is not as rapid as hydrocooling. However, it is adaptable to more types of produce and more flexible for smaller-scale operations. Forced-air cooling should be done quickly so produce does not lose too much moisture.

Hydrocooling

Cold water is an effective method for quickly cooling a wide range of vegetables in containers or bulk bins. Hydrocoolers use either an immersion or a shower system to bring products in contact with the chilled water. Hydrocooling avoids product water loss and may even add water to a slightly wilted commodity.

It is critical that water quality be maintained to reduce the spread of microorganisms, especially when hydrocooling water is recycled through the system multiple times. Use a water sanitation system such as chlorine, ozone, ultraviolet light or hydrogen peroxide to maintain appropriate water quality.

Package Icing

Some vegetables are cooled by filling the packed containers with crushed or flaked ice. Initially, the direct contact between the ice and product causes fast cooling. However, as the ice in contact with the product melts, the cooling rate slows considerably. Package icing is less efficient than forced air or hydrocooling and is not suited to many types of produce. Using liquid-ice, a slurry of ice and water, distributes ice throughout the container, achieving better contact with the product.

Table 6-2. Vegetable Cooling Methods

	RC	FA	HC	PI	VC
Asparagus	✓	✓	✓		
Beans		✓	✓		
Broccoli		✓	✓	✓	
Brussels sprouts		✓	✓	✓	
Cabbage		✓			✓
Carrots (with tops)		✓	✓	✓	
Carrots (without tops)		✓	✓	✓	
Cauliflower		✓			✓
Celery		✓	✓		✓
Cucumber	✓	✓	✓		
Eggplant	✓	✓			
Garlic	✓				
Herbs		✓			
Leafy greens		✓	✓		✓
Muskmelon		✓	✓	✓	
Onion (dry)	✓	✓			
Onion (green)			✓	✓	✓
Peas		✓		✓	✓
Pepper	✓	✓			✓
Potatoes	✓				
Squash (summer)	✓	✓			
Squash (winter)	✓				
Sweet corn		✓	✓	✓	✓
Sweet potato	✓		✓		
Tomato	✓	✓			
Watermelon		✓	✓		

RC – Room cooling
FA – Forced-air cooling
HC – Hydrocooling

PI – Package icing
VC – Vacuum cooling

Vacuum Cooling

This method involves water evaporation at very low atmospheric pressure. Vegetables that have a large surface area-to-volume ratio, such as lettuce and leafy greens, are best suited for vacuum cooling. There is approximately 1% product weight loss (mostly water) for every 6°C of cooling, and thus some coolers are equipped with a water spray system that adds water to the product surface during cooling. Capital equipment costs are high, so vacuum cooling is suited primarily to large operations.

Table 6-3. Storage Life for Fresh Vegetables in Commercial Storage

Commodity	Temperature (°C)	Relative Humidity (%)	Approx. Storage Life	Commodity	Temperature (°C)	Relative Humidity (%)	Approx. Storage Life
Asparagus	0-2	95-100	2-3 weeks	Melons			
Beans, green or snap	7-10	95	7-10 days	Honey dew	7	90-95	3 weeks
Beans, lima	3-5	95	5-7 days	Muskmelons (1/4-slip)	2-5	95	15 days
Beets, topped	0	98-100	4-6 months	Muskmelons (full slip)	0-2	95	5-14 days
Broccoli	0	95-100	10-14 days	Watermelons	10-15	90	2-3 weeks
Brussels sprouts	0	95-100	3-5 weeks	Mushrooms	0	95	3-4 days
Cabbage, Chinese	0	95-100	2-3 months	Okra	7-10	90-95	7-10 days
Cabbages, early	0	98-100	3-6 weeks	Onions, dry	0	65-70	1-8 months
Cabbages, late	0	98-100	5-11 months	Onions, green	0	95-100	3-4 weeks
Carrots, bunched	0	95-100	2 weeks	Onions, sets	0	65-70	6-8 months
Carrots, immature	0	98-100	4-6 weeks	Parsley	0	95-100	2-2.5 months
Carrots, mature	0	90-98	7-9 months	Parsnips	0	98-100	4-6 months
Cauliflower	0	95-98	3-4 weeks	Peas, green	0	95-98	1-2 weeks
Celeriac	0	97-99	6-8 months	Peppers, chili (dry)	0-10	60-70	6 months
Celery	0	98-100	2-3 months	Peppers, sweet	7-13	90-95	2-3 weeks
Chard	0	95-100	10-14 days	Potatoes, chipping	10	90-95	10 months
Chicory, witloof	0	95-100	2-4 weeks	Potatoes, early crop	4	90-95	7 days
Collards	0	95-100	10-14 days	Potatoes, late crop	4	90-95	5-10 months
Corn, sweet	0	95-98	5-8 days	Potatoes, seed	2-4	90-95	7 months
Cucumbers	7-13	95	10-14 days	Pumpkins	10-15	50-70	2-3 months
Eggplants	7-13	90-95	1 week	Radishes	0	95-100	3-4 weeks
Endive and escarole	0	95-100	2-3 weeks	Rhubarb	0	95-100	2-4 weeks
Garlic	0	65-70	6-7 months	Rutabagas	0	98-100	4-6 months
Greens, leafy ¹	0	95-100	10-14 days	Salsify	0	95-98	2-4 months
Horseradish	-1.0-0	98-100	10-12 months	Spinach	0	95-100	10-14 days
Kale	0	95-100	2-3 weeks	Squashes, summer	5-10	95	1-2 weeks
Kohlrabi	0	98-100	2-3 months	Squashes, winter	10-15	50-70	1-6 months
Leeks	0	95-100	3-6 months	Sweet potatoes	13-16	85-90	4-7 months
Lettuce	0	98-100	2-3 weeks	Tomatoes, firm-ripe	7-13	90-95	4-7 days
				Tomatoes, mature-green	13-21	90-95	1-3 weeks
				Turnips	0	95	4-5 months

¹ Leafy greens may be stored for 2-3 weeks if they have been hydro-cooled immediately after harvest.

Storage

Rapid, uniform cooling to remove field heat, followed by storing under proper conditions will ensure that a quality product reaches the consumer or processor.

See Table 6-3, *Storage Life for Fresh Vegetables in Commercial Storage*, this page, for recommended storage conditions for individual crops.

Storage Tips

Keep several thermometers in the storage area to help ensure the area is being uniformly cooled. Calibrate thermometers regularly to ensure that fresh produce is stored properly. Thermometers set into ice water should read 0°C. Change the wash water regularly

when washing fresh produce. This prevents the build-up of bacteria and other pathogens. Use chlorine at 150-200 ppm to eliminate rot-organisms from the surface of the product. Good storage conditions will maintain, not improve, the quality of produce in storage. Store only good quality produce.

Ethylene

Ethylene is naturally produced by most fruit and vegetables. It acts as a growth regulator and a ripening agent. Ethephon is a commercially available, synthetically produced ethylene product. It is widely used in the processing tomato industry (see *Chemical Fruit Ripening*, on page 213).

Ethylene gas increases the rate of ripening of mature fruits and vegetables, and shortens shelf-life. The effects of ethylene gas depend upon:

- the stage of produce maturity
- the temperature and relative humidity of the storage room
- the concentration of ethylene
- the exposure time

Ethylene is an invisible and odourless gas, however, its detrimental effects on produce can be easily misdiagnosed. Some of the undesirable effects of ethylene are:

- loss of green colour in some immature fruits (e.g., cucumbers and summer squash) and leafy vegetables
- accelerated ripening of fruits (e.g., tomatoes) during handling and storage
- russet spotting on lettuce
- bitterness (isocoumarin) in carrots
- sprouting of potatoes
- abscission of leaves (e.g., cauliflower, cabbage)
- toughening of asparagus

There are many sources of ethylene in the environment. The more important ones include internal combustion engines and ripening produce. Other sources include fluorescent ballasts, decomposing produce, cigarette smoke and rubber materials exposed to heat or UV light.

Use electric rather than gas-powered fork lifts where ethylene-sensitive commodities are present. Isolate internal combustion engines from handling and storage areas. Do not let engines idle in an enclosed loading space.

Simple ventilation of handling areas can prevent ethylene build-up, as long as the incoming air is not polluted. One complete air exchange per hour is usually sufficient.

Ethylene can be used to your advantage when controlled and careful ripening of fruits and vegetables is desired. In this case, commercially available ethylene generators are used.

For more information, see the OMAFRA Factsheets:

- *Storage of Cabbage*, Order No. 90-055
- *Troubleshooting Cold Storage Problems*, Order No. 94-083
- *Sizing and Laying Out a Short-Term (Summer) Refrigerated Storage for Fruits and Vegetables*, Order No. 92-124
- *Tunnel Forced-Air Cooler for Fresh Fruits and Vegetables*, Order No. 98-031

Table 6-4. Chilling Injury-Sensitive Vegetable Crops

Commodity	Min. Storage Temperature °C	Chilling Injury Symptoms
Asparagus	0-2	darkened, water-soaked tips leading to bacterial soft rot
Basil	7-10	wilting, water-soaked appearance
Beans (snap)	7-10	russetting, pitting, corky centres
Cantaloupe	2-5	pitting and surface decay
Cucumber	7-10	pitting and surface decay
Eggplant	7-13	flesh browning, pitting, decay of cap, fruit rot
Okra	7-10	pitting, discolouration, decay
Pepper	7-13	water-soaked appearance, darkening, fruit rot
Potato	2-10	browning, sweetening
Pumpkin	10-15	pitting, rot
Sweet potato	10	flesh discolouration, off-flavours, hard core, increased decay
Tomato (ripe)	7-13	rubbery texture, watery flesh, seed browning, decay
Tomato (mature green)	13	irregular ripening, poor texture
Watermelon	10-15	surface pitting, loss of flavour, fading of red colour
Winter squash	10-15	pitting, poor flavour, increased rot
Zucchini (summer squash)	5-10	surface pitting, rapid decay

Chilling Injury

Chilling injury occurs when a commodity is exposed to temperatures below its ideal storage range. The minimum storage temperature for each crop varies, as do the symptoms of chilling injury.

Chilling injury is not always easily recognized at the farm gate. Chilled produce often looks fine as it is removed from storage. However, as the temperature increases (in the grocery store or after purchase), symptoms begin to develop, and quality is quickly compromised.

Chilling injury may occur at any stage of the production and distribution line. The longer the chilling, the more significant the level of injury. The effects of multiple, short periods of chilling may be cumulative in some commodities. See Table 6-4, *Chilling Injury-Sensitive Vegetable Crops*, this page.

For more information, see the OMAFRA Factsheet, *Chilling Injury of Horticultural Crops*, Order No. 98-021.

Commodity Compatibility

Storage interactions occur between certain crops even if they have the same environmental requirements. Some crops give off volatile substances that interfere with the successful storage of others. For example, apples, pears, peaches, plums, apricots and tomatoes give off ethylene gas which, even in low concentrations, can cause undesirable effects in many vegetables (see *Ethylene*, on page 48). Potatoes may impart an earthy flavour to fruit, particularly at high temperatures. Do not store incompatible commodities in the same building unless special ventilation arrangements have been made.

Washwater Sanitation

Water is needed in many vegetable-packing systems to move, clean or cool produce. Inadequate sanitation of this water can lead to higher levels of post-harvest decay and food safety concerns. Chlorine is an effective sanitizer when used as outlined below:

- Start with drinking water quality water.
- Maintain free chlorine concentration between 100 and 150 ppm.
- Maintain washwater solution pH between 6.5 and 7.5.
- Change water daily or when it becomes turbid or cloudy (organic matter deactivates chlorine).
- Monitor free chlorine levels and pH constantly (minimum every hour) and replenish as required.

Sodium hypochlorite, calcium hypochlorite and chlorine gas can be used in washwater sanitation. Note that chlorine gas decreases the water pH while sodium hypochlorite and calcium hypochlorite increases water pH. If the water pH requires adjustments, this can be accomplished with muriatic acid (HCl) or citric acid.

Ozone, ultra-violet light and hydrogen peroxide are also effective methods of washwater sanitation. For more information on these methods, see the OMAFRA website at www.ontario.ca/omafra.

Storage Sanitation

Cleaning and sanitation in horticultural storage and packing areas are extremely important. Crop residue left from season to season is a prime source of the pathogens that cause post-harvest rots. Dried bacterial slime and fungal spores will survive on the walls and other surfaces for years. Consider every part of the storage system, including the floors, walls, ceilings, doors, refrigeration system, electrical conduits, piping, containers, pallets and machinery. A good sanitation program involves four steps: cleaning, disinfecting, rinsing and drying.

Cleaning

Remove debris, such as soil, wood, stones and metal, by brushing, vacuuming, scraping and high-pressure washing. Use a high-pressure washer with hot water and non-foaming industrial detergent. Water should be at least 38°C. Cleaning compounds such as detergents reduce the surface tension of water so that dirt and debris may be loosened and flushed away.

Disinfecting

Disinfecting follows the cleaning step. Dirt and residue will prevent the disinfectant from coming into contact with all surfaces. Many common disinfectants are deactivated by organic matter.

There are many products and procedures for sanitizing storages and equipment. Always refer to the product label for specific rates, exposure time and other environmental restrictions. Exposure time is generally 10 minutes, however this may vary with the chosen disinfectant.

Wear protective clothing (waterproof garment, safety glasses, rubber boots and gloves) during disinfecting and check the product label for specific safety instructions.

Rinsing and Drying

Rinse from the top down with clean (preferably drinking-quality) water. This will remove chemical residues and protect equipment from corrosion. Leave the storage area open to air dry. If possible, force outside air into the area. This will help remove unpleasant odours that may be transferred to the produce next season. Ensure no stagnant water remains in the storage area. Lingering humidity may encourage the development of mould and rot organisms.

For more information on storage sanitation, see the Agriculture and Agri-Food Canada Factsheet, *Hygiene Measures in Fruit and Vegetable Storage Warehouses*.

7. Integrated Pest Management

Integrated pest management (IPM) is an approach to managing pests that utilizes all available strategies to reduce pest populations below an economic injury level. IPM does not advocate a continuous pesticide spray program to eradicate pests. Instead, it promotes the integration of cultural, biological and chemical control strategies. By using these pest control strategies, the adverse effects of pesticides on the environment are minimized, and economic returns are maintained.

An IPM program makes control decisions based on:

- the pest (identification, biology and behaviour)
- beneficial organisms
- monitoring techniques
- use and timing of appropriate management tools
- resistance management strategies
- stage of crop growth
- recordkeeping

More detailed information on pest identification, biology, trapping, monitoring and recordkeeping techniques can be found in OMAFRA publications such as:

- Publication AF141, *Ontario CropIPM*
- Publication 700, *Integrated Pest Management for Onions, Carrots and Lettuce in Ontario: A handbook for growers, scouts and consultants* (Video also available)
- Publication 12, *Sweet Corn Production Manual*

Current information is also available on the OMAFRA website at www.ontario.ca/crops. Additional information is supplied via newsletters, meetings, field monitoring, demonstrations and pest management workshops. For more information on available IPM programs, contact OMAFRA's Agricultural Contact Centre at 1-877-424-1300, or the nearest OMAFRA Resource Centre.

Thresholds

An IPM program uses control guidelines (thresholds) that indicate when control measures should be taken to prevent economic losses. Spray guidelines for insect pests are based on an economic threshold where the lost income from not applying a control will be higher than the cost of applying a control. In

other words, some damage to the crop is tolerated, as long as this damage does not exceed the cost of the control. Thresholds for diseases, weeds, nematodes and vertebrates may be based on weather, site history, stage of crop development and field observations.

Monitoring

Monitoring is critical for the successful implementation of any IPM program. Monitoring allows growers to forecast and evaluate potential pest problems. Effective monitoring identifies the pest present, estimates its population and recognizes conditions favourable for pest development and damage.

Monitoring allows accurate timing of pest control measures, thus reducing pesticide use. Regular monitoring will also help identify minor or secondary pest populations before they cause significant damage.

Monitoring can include the use of traps and/or scouting. Good recordkeeping is an essential component of any IPM program. Keep a site map and records of:

- status of crop health and stage of crop
- population levels of pests and beneficials
- damage observed
- location of damage
- weather and other environmental conditions
- sprays and other control measures used

Trapping

Traps are useful for indicating the presence or absence and the relative abundance of insects. However, they often catch only the adult stage of the pest and may not provide specific information on the damaging immature stages. Weather monitoring can improve trapping efficiency by predicting insect emergence and development.

Traps are usually placed in the field 1–2 weeks prior to the estimated emergence of the insect. Both pheromone traps and visual traps are commonly used in vegetable crops. Pheromone traps use a female sex hormone lure to attract male adults. The lure is specific to each insect species, which makes insect identification easier. Visual

traps rely on a visual lure, such as a bright yellow sticky card, to attract the pest.

It is critical to the success of the trapping program that the correct type of trap is used for each target pest. The number of traps and the location within the field will also depend on the crop and insect. Specific monitoring guidelines are available in the publications listed at the beginning of this chapter and in the individual commodities sections in Chapter 9, starting on page 67.

Keep in mind that pheromone lures are specific to the pest being trapped. They are very sensitive to contamination if they come into contact with other types of pheromones. If your trapping program involves using different types of pheromones, wear disposable gloves to prevent cross-contamination during handling.

Scouting

One of the best ways to keep track of insects or the amount of disease present in the crop is to visually inspect the field. Scout fields at least once a week. More frequent monitoring is recommended when the pest is most active. Weed surveys taken across the field will aid in the selection of weed management strategies. Tools such as a hand lens or sweep nets can improve insect and disease scouting efficiency.

When scouting the crop, inspect plants in several different areas across the field for an accurate estimate of pest pressure. Pay special attention to the border areas and fencerows. These areas are favoured overwintering sites for many insect pests. Scouting guidelines (aimed at a specific crop or pest) often indicate the number of plants that should be inspected during scouting operations. In general, a minimum of 30 plants (sometimes as many as 50 to 100) should be inspected across the field before making any pest management decisions.

For a list of available crop consultants providing monitoring services, contact OMAFRA's Agricultural Contact Centre at 1-877-424-1300, or the nearest OMAFRA Resource Centre.

Pest Control Measures

Cultural and Mechanical

Integrated pest management incorporates cultural and mechanical practices to prevent or delay the development of pest outbreaks. Management tools include:

- site selection
- crop rotation

- resistant/tolerant cultivars
- certified, treated seed
- sanitation
- elimination of alternative hosts
- inter-cropping
- water management
- optimized plant health

The individual commodity sections in Chapter 9, starting on page 67, offer specific information utilizing all of the available management practices to prevent and manage pests.

Crop Rotation for Control of Diseases

Crop rotation can be an important practice for preventing some diseases caused by fungi, bacteria and nematodes. Rotation with non-susceptible crops for 3 years usually allows enough time for plant material in the soil to completely decompose. In the absence of susceptible plant material, these organisms die off. For some soil-borne pathogens, such as *Phytophthora* in peppers and cucurbit crops, a rotation longer than 3 years may be required.

Rotation only works when successive crops are not susceptible hosts. It is important to remember that plants in the same family (e.g., potatoes, tomatoes, peppers and eggplant) may all be susceptible to the same disease organisms. Do not rotate with plants in the same family.

A list of recommended rotational crops is available in the individual commodities sections of Chapter 9, starting on page 67.

Some diseases that are spread by wind or by insects may not be controlled by crop rotation. For example, some leaf blight organisms and powdery mildew fungi can blow into fields from neighbouring weeds and infested fields. However, crop rotation will reduce the level of many disease-causing organisms that remain on crop residue left in a field.

Chemical Controls

Chemical controls include synthetic, inorganic and biological pesticides. They kill target pests and limit subsequent populations. They are important tools for crop protection when used as part of an IPM program.

Understand the pest's life cycle and apply chemicals at the stage when the pest is most vulnerable. Select the appropriate product for the target pests.

To control insects, monitor fields closely. Spray according to action thresholds or at critical stages of crop development.

To control disease, apply fungicides prior to disease infection and development. Use factors such as weather conditions, crop stage and (where available) disease prediction models to indicate fungicide spray timing.

Prevent Bee Poisoning

Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops are a source of nectar or pollen for honey production.

If insecticides are used for insect control, take the following steps to prevent harming bees:

- Before applying a pesticide, advise local beekeepers, so that they take additional precautions to protect the bees. Contact the Provincial Apiarist at 1-888-466-2372, extension 63595, for a list of the beekeepers in your area.
- Do not spray any flowering crop on which bees are foraging. If you must apply insecticides, spray after 7 pm when the bees are not foraging.
- Prevent drift. Do not apply insecticide on windy days or during periods of dead calm.
- When there is a choice, choose the product formulation that is less hazardous to bees. Dusts are more toxic than sprays. WP formulations are more toxic than EC formulations.

Most organophosphate and carbamate insecticides are highly toxic to bees. Examples of insecticides used in crop production that are very toxic to bees are listed in Table 7-1, *Relative Toxicity of Insecticides to Honeybees*, this page.

Read each pesticide label for specific precautions regarding bees.

Table 7-1. Relative Toxicity of Insecticides to Honeybees

Common Name	Trade Name(s)
Highly Toxic Do not apply to flowering crops.	
abamectin	Agri-Mek 1.9EC
acephate	Orthene
carbaryl	Sevin XLR
chlorpyrifos	Lorsban 15 G, Lorsban 4 E, Lorsban 50W, Pyrifos 15 G, Pyrifos 50 W, Pyrinex 480 EC
clothianidin	Clutch 50 WDG
cypermethrin	Ripcord 400 EC, UP-Cyde 2.5 EC
deltamethrin	Decis 5EC
diazinon	Diazinon 500 E, Diazinon 50W
dimethoate	Cygon 480AG; Lagon 480E
imidacloprid	Admire, Grapple, Alias 240 EC
lambda-cyhalothrin	Matador 120EC, Silencer 120 EC
malathion	Malathion 25W, Malathion 500 E
methamidophos	Monitor
methomyl	Lannate
naled	Dibrom
oxamyl	Vydate L
permethrin	Pounce, Perm-UP 3.2 EC, Ambush 500 EC
phosmet	Imidan 50WP
spinetoram	Delegate WG
spinosad	Success 480SC, Entrust 80W
thiamethoxam	Actara 25 WG
Moderately Toxic Apply only during late evenings or early mornings.	
acetamiprid	Assail 70WP
captan	Supra Captan 80 WDG, Maestro 80 DF
endosulfan	Thiodan 4EC, Thiodan 50WP, Thionex 50WP
pirimicarb	Pirimor 50DF
spirotetramat	Movento

Biopesticides

Biopesticides are derived from natural materials such as plant extracts, bacteria and minerals. In Canada, biopesticides are divided into two major classes, microbial pesticides and biochemical pesticides.

Microbial pesticides contain a beneficial microorganism, such as a bacterium, fungus, virus or protozoan, as the active ingredient. They are relatively specific to their target pest. Microbial pesticides registered for use in vegetables include *Bacillus subtilis* and the various subspecies and strains of *Bacillus thuringiensis*.

Biochemical pesticides are naturally occurring substances and/or their synthetic analogues. A synthetic analogue is a manufactured molecule that resembles a naturally occurring substance. They generally control pests by different mechanisms than conventional pesticides or by making crops unsuitable for feeding. While many biopesticides are less toxic and pose a lower risk than conventional pesticides, some can be quite toxic.

Although many biopesticides are formulated, packaged and applied in a similar fashion to conventional pesticides, it is important to remember that the active ingredients on which they are based are often quite different. Biopesticides may require a specific timing of application, or they may only affect certain growth stages of the target pest.

Table 7–2. Biopesticides Used on Vegetable Crops in Ontario

Common Name	Trade Name(s) ¹	Insecticide (i) Fungicide (f)	Crops Registered ¹	Notes
kaolin clay	Surround	i	carrots, celery, cucurbits, lettuce, parsley,	This product leaves an insect-repelling white film on all plant parts. Re-application will be necessary following periods of heavy rain, overhead irrigation or rapid plant growth. Do not spray when bees are active in the crop.
<i>Bacillus thuringiensis</i> (Bt)	Novodor, Dipel, Thuricide, Bioprotec	i	beans, brassicas, celery, herbs, lettuce, parsley, potatoes, spinach, sweet corn, tomatoes	Bt is a stomach toxin and must be ingested by the target insect. It is most effective when applied to smaller instar larvae. Thorough coverage of the feeding area is essential.
potassium bicarbonate	Milstop Foliar fungicide	f	cucurbits, peppers	Disease suppression only. This contact fungicide kills certain types of fungi by pulling water from the spores and cell walls. It has little residual activity. Apply prior to the development of disease symptoms.
<i>Bacillus subtilis</i>	Serenade	f	celery, lettuce, onions	Disease suppression only. This beneficial bacterium colonizes plant parts and helps prevent plant pathogens from becoming established. Apply prior to the development of disease symptoms. Copper is toxic to <i>B. subtilis</i> . Do not use in rotation with copper fungicides.

¹ Where multiple trade names exist, not all crops are necessarily registered on each product. Always consult the product label for specific crop recommendations.

Biopesticides, particularly those that are based on live microbes, are often highly sensitive to environmental conditions, such as heat or sunlight, which can reduce their effectiveness. Always consult the product label for specific usage instructions prior to spraying.

Table 7–2, *Biopesticides Used on Vegetable Crops in Ontario*, this page, lists the various registered biopesticides and their characteristics.

Beneficial Insects (Beneficials)

Beneficials are natural enemies of the crop pest. These predators (including parasites and pathogens) help suppress pest populations.

Beneficials will not completely eliminate damage by pests. However, once they are established, they can maintain pest populations at lower levels. They are also effective at controlling indirect pests such as aphids, leafhoppers and mites. Beneficials are less effective at keeping populations of direct pests (those attacking the harvested product) at levels acceptable for commercial production. One of the advantages of beneficial insects is that their activities can prevent or delay the development of pesticide resistance. Where possible, select chemical control products that will not harm the beneficials.

Resistance Management

Resistance is the ability of a pest to survive exposure to a pesticide that previously controlled it. Resistance to a pesticide develops after repeated exposure to a specific chemical or chemical family. A few naturally occurring resistant individuals survive after each spray, while the

susceptible portion of the population is killed. These resistant survivors multiply and gradually replace the susceptible ones. Eventually the resistant population dominates, and the pesticide loses efficacy.

There are many potential causes for pest control failures. Before assuming a population is resistant to a product, consider the following factors: product selection, water volume, rate, calibration and coverage, timing, water pH, time required for knockdown of pest and weather conditions.

Resistance to pesticides can develop very quickly. Do not use the same chemical repeatedly unless it is used in rotation with a different chemical or used in combination with other chemicals having a different mode of action.

Many chemicals with the same active ingredients are marketed under different brand names. For example, the insecticide chlorpyrifos is marketed under the brand names Lorsban, Pyrifos and Pyrinex.

Different chemicals may also have the same mode of action. For example, both Assail and Admire have the same mode of action. Using Assail after Admire is equivalent to using Assail after Assail, since resistance to both chemicals develops at the same time, even though only one may have been used repeatedly.

Certain pests are more prone to develop resistance to pesticides than others. Pests with a short life cycle and many generations per growing season are more likely to develop resistance. Pests are more likely to develop resistance to pesticides that have a single mode or site of action than to those with multiple modes of action.

Table 7-3. Insecticide Groups Based on Sites of Action

The classification scheme listed below is adapted from
the Insecticide Action Committee Mode of Action Classification (IRAC) V5.3 (August 2008).

Group #	Primary Site of Action	Group Name	Product name(s)
1A ¹	Acetylcholinesterase inhibitors	carbamate ¹	Lannate TNG, Sevin XLR, Vydate L
1B		organophosphate	Agrox B-2, Agrox CD, Counter 15 G, Cygon 480, Diazinon 50 W, Diazinon 500 E, Dibrom, Imidan 50 WP, Lagon 480, Lorsban 4E, Lorsban 15 G, Malathion 25 W, Malathion 500 E, Monitor 480, Orthene 75 SP, Pyrifos 15 G, Pyrifos 50 W, Pyrinex 480 EC, Thimet 15 G
2A	GABA-gated chloride channel agonists	cyclodiene organochlorines	Thiodan 4 EC, Thiodan 50 WP, Thionex 50 W
3	Sodium channel modulators	pyrethroid	Ambush 500 EC, Decis 5 EC, Force 3.0 G, Matador 120 EC, Methoxychlor 240, Perm-UP 3.2 EC, Pounce 384 EC, Ripcord 400 EC, Silencer 120 EC, UP-Cyde 2.5 EC
4	Nicotinic acetylcholine receptor agonists	neonicotinoids	Admire 240 F, Assail 70 WP, Actara 240 SG, Actara 25 WG, Alias 240 EC, Clutch, Cruiser 5 FS, Gaucho 480 FL, Grapple, Poncho 600, Titan ST
5	Nicotinic acetylcholine receptor allosteric agonists	spinosyns	Success 480 SC, Entrust 80 W, Delegate WG
6	Chloride channel activators	avermectins	Agri-mek 1.9%
9B	Selective feeding blockers	pyridines	Fulfill 50 WG
11	Microbial disruptors of insect midgut membranes	biological	Novodor, Dipel, Thuricide, Bioprotec
15	Inhibitors of chitin biosynthesis, type 0, Lepidopteran	benzoylureas	Rimon
17	Moulting disruptor, dipteran	cyromazine	Citation 75 WP, Governor 75 WP
23	Inhibitors of lipid synthesis	tetronic acid derivatives	Forbid 240 SC, Movento 240 SC, Oberon
28	Ryanodine receptor modulators	diamides	Coragen
NC	not classified		Surround

¹ Although sharing the same primary target site, it is possible that not all members of a single major mode of action (MoA) class have been shown to be cross-resistant. However, for the purposes of this classification system, it should be assumed that cross-resistance exists between compounds in any one sub-group.

See Table 7-3, *Insecticide Groups Based on Sites of Action*, this page, and Table 7-4, *Fungicide Groups Based on Mode of Action*, next page, for a list of chemical families and their modes of action.

The pest control recommendation tables in Chapter 9, *Crop Management Recommendations*, starting on page 67, list the chemical group for each control product. Over the course of the season, rotate between products from different chemical groups.

Steps to Delay the Development of Pesticide Resistance

- Rotate between products from different chemical groups. Avoid the repeated use of any one pesticide or group of pesticides.
- Follow the pesticide label. Many products make specific recommendations about the maximum number of sequential applications and the maximum number of total applications permitted in one season.
- When applying a pesticide, use the appropriate rate, timing, water volume, nozzle selection and water pH.
- Ensure the sprayer is well maintained and properly calibrated.

- Follow an IPM program that makes use of a variety of different pest management strategies, including monitoring, crop rotation, cultural, biological and chemical options.
- Spray insecticides only when necessary. Use established thresholds where available.
- Apply fungicides preventatively before disease occurs. Wherever possible, follow disease prediction models. Applying fungicides in an attempt to eradicate a disease after it has become established is rarely effective and it can increase the risk of selecting for resistant populations of the pathogen.
- When tank-mixing pest control products, ensure that each component belongs to a different chemical group with a different mode of action.
- If you experience a control failure after using a registered product, do not reapply the same pesticide.
- Keep accurate records of the type of product used during each application throughout the season.

Resistance can be costly to the grower. The development and registration of new products is expensive and time-consuming. Judicious use of pesticides will help reduce the development of resistant populations and conserve the effectiveness of existing products.

Table 7–4. Fungicide Groups Based on Mode of Action

This classification scheme is based on the Fungicide Resistance Action Committee (FRAC) List, 2009

Group #	Primary Site of Action	Group Name	Product Name(s)	Risk of Developing Resistance
1	Inhibition of mitosis (tubulin formation)	methyl-benzimidazole carbamates	Senator 70 WP	High
2	Affect cell division, DNA & RNA synthesis & metabolism	dicarboximide	Ronilan EG, Rovral WP	Moderate to High
3	Inhibition of sterol synthesis	DMI (demethylation inhibitor)	Nova 40 W, Tilt 250 E, Topas 250 E, Mission 418 EC, Bumper 418 EC	Moderate
4	Affect RNA synthesis	phenylamides	Allegiance FL, Apron FL, Apron Maxx, Apron XL LS, Ridomil 1G, Ridomil Gold 480 EC, Ridomil Gold MZ, Ridomil Gold MZ 68 WP	High
7	Fungal respiration	carboxamide	Lance WDG, Vitaflo 280, Pristine WG	Moderate
9	Methionine biosynthesis	anilino-pyrimidines	Scala SC, Switch 62.5 WG	Medium
11	Fungal respiration	quinone outside inhibitors (QoI)	Cabrio EG, Headline EC, Quadris, Reason 500 SC, Tanos 50 DF, Pristine WG	High
12	Osmotic signal transduction	phenylpyrroles	Apron Maxx, Maxim 480 FS, Maxim MZ, Scholar 62.5 WG	Low to Moderate
13	Osmotic signal transduction	quinolines	Quintec	Moderate
14	Lipid peroxidation (proposed)	aromatic hydrocarbons	Botran 75 W, Quintozene 75 WP	Low to Moderate
21	Fungal respiration	quinone inside inhibitors (QoI)	Ranman 400SC	Medium to High
22	Mitosis and cell division	benzamide	Gavel 75 DF	Low to Moderate
25	Protein synthesis	antibiotic	Streptomycin	High
27	Unknown	cyanoacetamide oxime	Curzate 60 DF, Tanos 50 DF	Low to Moderate
28	Cell membrane permeability (proposed)	carbamate	Tango C	Low to Moderate
29	Uncoupler of oxidative phosphorylation		Alto 500 F	Low
33	Unknown	phosphonate	Aliette WDG	Low
40	Cell wall synthesis (proposed)	carboxylic acid amides	Acrobat 50 WP, Revus	Low to Medium
44		microbial	Serenade ASO, Serenade Max, Prestop	Low
M1	Multi-site, contact	inorganic	Copper Spray, Copper 53 W, Kocide DF, Kocide 2000, Oxidate, Parasol WP	Low
M2	Multi-site, contact	inorganic	Microscopic Sulphur	
M3	Multi-site, contact	dithiocarbamate	Acrobat 50 WP, Dithane, Dithane F 45, Ferbam 76 WDG, Gavel 75 DF, Manzate DF, Maxim MZ, Penncozeb 80, Polyram DF, Thiram 75 WP, Vitaflo 280, Zineb 80 W	Low
M4	Multi-site, contact	phthalimide	Agrox B-2, Agrox CD, Captan, Maestro 75 DF, Supra Captan 80 WDG	Low
M5	Multi-site, contact	chloronitrile	Bravo 500, Tattoo C	Low
NC	Not Classified	Not classified	MilStop, Superior Oil 70	Resistance not known

Spraying Vegetable Crops

Water Volumes

Most insecticides/fungicides are applied with 135–450 L/ha of water. Herbicide applications range from 55–350 L/ha. Many fungicide labels specify a specific minimum water volume to ensure adequate spray coverage of plant surfaces and optimize the product's performance.

Nozzle Selection

All agricultural spray nozzle manufacturers classify the range of droplet sizes produced by each of their nozzles. The nozzle manufacturers use charts or tables to show droplet size classification factoring in the nozzle type, nozzle size and operating spray pressures (psi).

The American Society for Agricultural and Biological Engineers (ASABE) Standard S-572 classifications include:

VF = Very Fine
F = Fine
M = Medium
C = Coarse
VC = Very Coarse
XC = Extremely Coarse

Most fungicides and insecticides require medium or medium-to-fine spray droplets. Fine or very fine droplets may be easily carried off by the wind or evaporate before hitting the target, resulting in poor spray coverage. Poor spray coverage is a common cause of control failures. Coarse or very coarse sprays are useful to prevent spray drift of herbicides, however, they may not provide sufficient coverage of plant surfaces for insecticides or fungicides.

Table 7–5, *Sample Droplet Size Classification Chart*, this page, is an example of droplet size charts often used by nozzle manufacturers. It is important to select the right type of nozzle and to operate it at the right pressure to produce the appropriate droplet size.

Table 7–5. Sample Droplet Size Classification Chart

Examples of Nozzle Types	PSI					
	40	50	60	70	80	90
Hollow cone	F	F	F	VF	VF	VF
Flat fan	M	M	F	F	F	F
Drift reducing flat fan	C	C	M	M	M	M
Low pressure air induction flat fan	C	C	C	M	M	M
High pressure air induction flat fan	XC	XC	XC	XC	VC	VC

In the past, hollow cone nozzles were commonly used to apply fungicides or insecticides. This type of nozzle produces a finer and more uniform spray distribution than solid cone nozzles. Hollow cone nozzles are particularly suited to the application of wettable powders, flowables and suspensions. Solid cone nozzles are used when increased penetration into the crop canopy is required.

Equally spaced flat fan nozzles provide uniform spray distribution across the whole boom. They are frequently used for herbicide applications. Flat fan nozzles are becoming more common for fungicide and insecticide application. The pumps on many large, self-propelled sprayers cannot produce sufficient pressure to properly operate hollow-cone nozzles. A large number of flat fan nozzle types are available to produce a medium or medium-to-fine spray at operating pressures less than 100 psi.

Coverage

Coverage can be defined as the number of discrete spray droplets per target area. Good coverage of both the upper and lower leaf surfaces is an essential component of the performance of many fungicide and insecticides.

Water sensitive paper is a tool that can be used to assess spray coverage in the field. Table 7–6, *Water Sensitive Paper – Recommended Droplet Density*, this page, illustrates the recommended droplet density per square centimeter for insecticide, herbicide and fungicide applications.

Air Temperature and Relative Humidity

Pesticides can cause phytotoxicity or burning of plant foliage or flowers if applied during very hot weather (temperatures above 27°C). In hot conditions, avoid applications between 10:00 AM and 2:00 PM, as plants will be more prone to injury. The water droplets themselves can, at times, act as tiny magnifying lenses causing plant injury. Spraying during hot conditions may also cause a large portion of the spray droplets to evaporate before they hit the target.

Table 7–6. Water Sensitive Paper – Recommended Droplet Density

Number of droplets per square centimeter	Application Type
20–30	insecticides
20–30	herbicides (pre-emergence)
30–40	contact herbicides (post-emergence)
50–70	fungicides

During conditions of high relative humidity (>80% relative humidity), the drying of the spray materials will be delayed. Slow and prolonged drying of pesticides can lead to phytotoxicity in some instances.

Synthetic pyrethroid insecticides (Ripcord, Decis, Pounce, Matador, etc.) break down quickly when air temperatures are above 27°C, reducing their effectiveness. If possible, apply these in the evening, when temperatures have dropped, or select a different product.

Rainfall

The decision to spray just prior to a rain or shortly after should be based on plant protection. This may be more critical when applying fungicides. All fungicides are most effective if the leaf is adequately covered prior to infection. Waiting for the rain to stop before the initial application may allow disease organisms to invade unprotected plant tissue. Once they have dried, most fungicides can withstand about 2.5 cm of rainfall and still provide adequate protection.

Many preemergent herbicides are best applied before a rain. Moist soils allow for better distribution of the herbicide within the seed zone. Post-emergent applications are best applied after a rain or should be timed to allow adequate drying prior to rainfall.

Wind Speed & Drift

When applying fungicides and insecticides, moderate air movement helps move the product in and around the crop. In addition, light winds will help in the drying process. Optimum air movement is 3–8 km/h.

Do not spray when wind speeds are high or gusty. Drift is also possible at lower wind speeds and even under no-wind conditions. Drift potential is affected by the interaction of travel speed, wind speed and droplet size. For more information on preventing pesticide drift, see *Manage Drift*, on page 217.

8. General Pests of Vegetable Crops

There are a number of pests that attack a wide range of crops. Descriptions of the common pests and cultural control methods are listed here.

For chemical control methods, see the individual commodity sections in Chapter 9, *Crop Management Recommendations*, on page 67.

Diseases

Damping-Off and Root Rots (*Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Penicillium*)

Crops Affected: Most vegetable crops.

Symptoms: Seedlings affected by damping-off generally rot at ground level and topple over. Other symptoms may include seed decay, rotting roots and cankers on the stem or lower petioles.

Plants are usually infected by damping-off during the seedling stage. Cool, wet springs and conditions conducive to slow emergence and delayed early development are particularly problematic.

Root rots generally occur during periods of warm, wet weather and may affect the plant at any stage of development. Certain species of *Fusarium* and *Rhizoctonia* may cause root rot problems during hot, dry conditions.

Thresholds: None have been established.

Management Notes: Sterilize flats and use only sterile soil-less mixture for growing seedlings (see *Transplanting*, on page 39). Use fungicide-treated seed and plant only when soil and weather conditions are favourable for vigorous crop development. See also Table 5-3, *Minimum Soil Temperatures for Vegetable Seed Germination*, on page 38.

See the commodity sections of Chapter 9, starting on page 67, for seed treatment recommendations.

Viruses (General)

Crops Affected: Most vegetable crops.

Depending on the crop, virus diseases may be spread by aphids and/or other leaf-feeding insects. Virus particles are usually acquired from infected plants. Insects can carry and transmit a virus for their entire life (persistent transmission) or for only a short time (non-persistent transmission). Management options and control tactics vary considerably between persistent and non-persistent viruses.

In persistent transmission, an insect can become infected after feeding on an infected plant for an extended period of time (at least several minutes to 1 hour). After an incubation period (sometimes several days or weeks), the insect is able to spread the virus for the rest of its life. These viruses are often found where the insect pest has formed large colonies on a plant. A good insect management program including pesticide applications can help reduce the spread of persistent viruses. An example of persistent virus transmission is the spread of tomato spotted wilt virus by western flower thrips.

Migratory aphids, including the soybean aphid, are common vectors of many non-persistent viruses. These aphids often feed for only short periods of time on vegetable crops before moving to new food sources. They do not necessarily form colonies within a specific field.

When an aphid lands on an infected plant, it can acquire a non-persistent virus on its stylet (mouthparts) within less than one minute of feeding. If the aphid then moves on to sample a new plant, the virus is spread from the infected plant to a healthy plant. As an aphid feeds, it clears the virus from its mouthparts and is no longer able to transmit the disease to additional plants. Once the problem is identified, the aphids have already moved on, making insecticide applications inefficient for the control of non-persistent virus diseases. Examples of non-persistent viruses include bean common mosaic and cucumber mosaic virus.

The use of clean seed, resistant varieties and the management of alternative hosts, including weeds in and around the field, can reduce sources of viruses.

Crop borders of non-virus host plants and mineral oils have been used to manage the spread of non-persistent viruses in some crops. Most of the common viruses affecting vegetable crops are non-persistent viruses.

For virus symptom identification, see the specific crop sections in Chapter 9, starting on page 67.

Insects

Aphids

Crops Affected: Most vegetable crops.

Symptoms/Identification: Aphids are small, soft-bodied, pear-shaped insects, with cornicles or "tail-pipes" near the tip of their abdomen. They have relatively long legs and prominent antennae. Colour may vary depending on the species and the host plant. A few species found in vegetable crops have a waxy or woolly appearance. They are typically found in colonies located on the underside of the leaf or along the stem or petioles.

Aphids pierce the leaves and suck the sap from plants. Severe feeding causes leaf distortion. They also produce a sticky substance called "honeydew," which can promote the development of secondary moulds (sooty mould). These moulds may affect the marketability of the harvested product.

Aphids also act as a primary vector of several economically significant virus diseases (see comments under *Viruses (General)*, previous page). The soybean aphid does not form colonies on vegetable crops; however, it often moves through vegetables in its search for soybeans, spreading non-persistent viruses as it travels. The control of aphid populations with conventional insecticides does little to prevent the spread of non-persistent viruses.

Period of Activity: Aphids are present throughout most of the growing season. Part of their seasonal lifecycle involves asexual reproduction, with females giving birth to live offspring. This allows for rapid build-up of numbers under favourable conditions, including hot, dry weather. Aphid populations are often kept below threshold levels where predators (lady beetles, lacewings, minute pirate bugs, etc.) are present in abundance.

Thresholds:

Peppers	No threshold is established, but more than 10 aphids per leaf could be potentially damaging.
Sweet corn	10% of ears infested (ears with more than 20 aphids are considered infested).
Tomatoes	5 aphids per 10 leaflets per plant.
Potatoes*	4 aphids per leaf (check 1 lower leaf on 50 plants).

* Keep seed potato fields free of aphids at all times.

Management Notes: The continuous use of broad-spectrum insecticides may disrupt beneficial populations, resulting in aphid resurgence. Note that the sunflower aphid and the green peach aphid may have developed resistance to insecticides in some areas.

For more information, see the OMAFRA Factsheet, *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053.

Cutworms

Crops Affected: Many vegetable crops.

Symptoms/Identification: There are several species of cutworm. The larvae are soft and fat, and they roll up when disturbed. Look for cutworm larvae in the top 2.5 cm of soil surrounding the damaged plant. Early-season cutworms attack the seedling plants, usually cutting them below or at the soil surface. A single larva may destroy several seedlings.

Period of Activity: Most species of cutworms feed at night, hiding during the day in the soil near the base of the plant. Plants at the seedling stage are most vulnerable to cutworm losses.

The variegated cutworm appears later in the season. It is larger than the other cutworm species and feeds on the foliage of tomatoes, potatoes and eggplant, as well as damaging and contaminating tomato fruit.

Black cutworms may cause serious damage in potatoes by feeding on the tubers late in the season.

Thresholds: For most vegetable crops, the control guideline is 5% damaged plants.

Other thresholds are as follows:

Cutworm

Potatoes	Sporadic pest. Monitor populations with pheromone traps.
Sweet corn	10% damage, if plants are less than 4–6 leaves and larvae are less than 4 cm (1.5 in.)

Variegated cutworm

Tomatoes (scouting)	1 larva per 30 plants
Tomatoes (pheromone traps)	7 moths per trap per week. Use delta or wing traps in combination with field scouting.

Management Notes: Migrating female moths are attracted to weedy fields in the early spring for egg-laying. Damage is often sporadic.

Cutworm control is most effective on small (<2.5 cm) larvae. Larger larvae are difficult to control with insecticides. At more mature stages (>2.5 cm in length), they cease feeding as they prepare to pupate, and control becomes unnecessary.

Apply insecticides in the early evening, as the cutworms come to the surface to feed at night. Insecticides are more effective on moist soils.

See the individual commodity sections in Chapter 9, starting on page 67, for cutworm chemical control recommendations.

For more information, see the OMAFRA Factsheet, *Managing Cutworms in Vegetable Crops*, Order No. 00-055.

Millipedes

Crops Affected: Many direct-seeded vegetables, carrots, radishes and sweet potatoes.

Symptoms/Identification: Millipedes are normally considered beneficial in vegetable production due to their habit of feeding on decaying plant material, which helps to incorporate organic matter into the soil. However, under certain conditions millipede populations can build to high levels and may damage the roots and seedlings of a variety of crops.

There are several different types of millipedes present in Ontario soils. They range in size from 1–2.5 cm in length. They are typically dark grey in colour. They are heavily segmented with a pair of legs on each segment.

Millipedes are frequently confused with wireworm. See *Wireworm*, next page.

During cool, wet springs, millipedes may feed on ungerminated seed and young seedlings. Millipedes are not usually an aggressive pest on direct-seeded crops. However, when combined with other stresses such as cold soils, fungal pathogens or other insect pests, millipedes have been known to affect plant populations and seedling vigour.

Later in the season, millipedes may feed on root crops such as carrots, radishes and sweet potatoes. Damage ranges from superficial feeding on the skin, to fine tunnelling into the flesh or shallow cavities with ragged edges. This damage impacts the crop's marketability.

Period of Activity: Recent studies conducted in Ontario suggest that millipedes are most active in the early spring and late summer. Crop damage may be more severe under dry soil conditions when the millipedes feed on the root as a source of moisture.

Seedcorn Maggot

Crops Affected: Seedcorn maggots are generalist feeders and attack a wide variety of vegetable crops, including beans, cucurbits, nappa cabbage, onions, potatoes and sweet corn.

Symptoms/Identification: These small white maggots feed on swollen, ungerminated seeds or inside the succulent young stem tissue. Poor stand establishment is often a symptom of infestation.

Seedcorn maggot flies will lay eggs inside the heads of nappa cabbage during hot, dry conditions. Larvae then feed on the inner leaves, creating a ragged appearance, rendering the heads unmarketable.

Period of Activity: Maggots are usually a problem during cool, wet springs when germination is delayed. The first generation of adult flies lay their eggs from April until the middle of June. There are several generations per year in Ontario, however, the first generation is generally the most damaging.

Thresholds: None have been established.

Management Notes: Use one of the insecticide seed treatments recommended in the commodity sections of Chapter 9. Egg-laying females are attracted to moist soils and the odour of decaying organic matter. Discourage egg-laying by applying manure or incorporating winter cover crops well in advance of planting.

Slugs

Crops Affected: Beans, celery, brassica crops, eggplant, leafy vegetables (lettuce, chicory, endive), peppers, potatoes, rhubarb, sweet corn and tomatoes.

Symptoms/Identification: These soft-bodied, legless, grey mollusks feed above or below ground, depending on the soil moisture level. Slugs have rasping mouth-parts and will create ragged holes on the lower leaves, sometimes leaving a "window-pane" of waxy cuticle behind.

Severely affected plants may become skeletonized. Under high populations, slugs also attack seeds and emerging seedlings. A slime trail is usually observed at the feeding location.

Period of Activity: Slug damage is most severe in years when there is prolonged cool, wet weather during May and June.

Thresholds: None have been established.

Management Notes: Most plants can successfully outgrow light feeding damage. Cultivating fields where slug pressure is high can help reduce the slug population. Tillage exposes the slugs to dehydration and predation by birds and mammals.

Removing weeds and crop residue from the zone immediately surrounding young seedlings may also help reduce damage. Zone tillage can remove slug habitat while maintaining the benefits of reduced tillage.

See the commodity sections of Chapter 9, starting on page 67, for chemical control recommendations.

Tarnished Plant Bug

Crops Affected: The tarnished plant bug (TPB) feeds on over 300 species of fruit, vegetable and field crops, as well as numerous weed species. Most crops discussed in this publication are susceptible to attack. Problems with TPB may occur in beans, celery, brassica crops (including specialty crucifers), cucurbits, eggplants, lettuce, peppers, potatoes and tomatoes.

Symptoms/Identification: Nymphs are greenish in colour, with well-developed legs and moderately long antennae. Later instars have wing pads and circular black spots on the thorax, behind the head. Adults are pale green or yellow-to-dark brown, with dark markings. They have wings that are partly membranous and partly thickened. Both the nymphs and adults have piercing-sucking mouthparts. They cause a broad range of symptoms on vegetable crops including:

- stings and lesions on celery stalks

- reduced fruit set on beans, peppers and eggplants
- stings and blemishes on tomato and pepper fruit
- necrotic spots on the florets and curd of broccoli, cauliflower
- small holes with brown margins on lettuce leaves
- dead leaves on potatoes and vine crops

Period of Activity: The TPB is a sporadic pest, present in Ontario throughout the growing season. Adults are highly mobile, moving readily from adjacent crops when disturbed by harvest activities. There are two generations per year in most growing regions within Ontario, with a partial third generation in more southerly parts of the province.

Thresholds:

Celery and lettuce	0.1 to 0.2 TPB per plant
Tomatoes	1 nymph or adult per 30 plants (after fruit set)

Management Notes: TPB breed on many common weed species, including chickweed, dandelion, lamb's-quarters, ragweed and fleabane. Weed control in and around vegetable plantings will help reduce potential infestations. Alfalfa is also a very attractive host. After the alfalfa is cut, tarnished plant bug adults may disperse and invade nearby vegetable crops.

Wireworm

Crops Affected: Carrots, onions, sweet corn, potatoes, vine crops, eggplant, potatoes, tomatoes, peppers, sweet potatoes and sugarbeets.

Symptoms/Identification: Wireworms are the larvae of click beetles. The larvae are copper-coloured, cylindrical and hard-bodied. They have 3 pairs of tiny legs near the head-end and are commonly confused with multi-legged millipedes and symphylans.

Wireworms can be seen burrowing into the ungerminated seeds, as well as underground roots and stems of plants. Infested plants do not develop well, and seedlings lack vigour or fail to emerge. Damage is often scattered randomly across the field. In the fall, wireworm feeding may render sweet potatoes, carrots and potatoes unmarketable.

Period of Activity: Wireworms are present all season. Young plants are most susceptible, therefore early-season control is critical. Wireworms have a life cycle of several years. They are likely to be present in fields with a history of the problem or in fields that have recently had sod crops. Some species require several years to complete development.

Thresholds: Wireworms may be monitored in the fall (or in the early spring for later-planted crops) using bait stations. Bury whole carrots, 7.5 cm deep, at 10 marked stations across the field. Check the stations in 2–3 days. An average count of 0.5–1 wireworm per station indicates a potential problem. Make your planting and seed treatment decisions accordingly.

Management Notes: See the individual commodity sections of Chapter 9, starting on page 67, for a list of registered insecticide-seed treatments and in-furrow control options. Planting into well-prepared, warm soils and avoiding unnecessarily deep planting depths will help encourage early-season growth, reducing the incidence of this pest. There are several species of wireworms present in Ontario, with varying degrees of susceptibility to registered insecticide seed treatments.

White Grubs

Crops Affected: Beets (table), brassica crops, potatoes, sweet potatoes and sweet corn.

Symptoms/Identification: White grubs are the larvae of the June beetle, the European chafer and (in some areas) the Japanese beetle. The grubs have six legs with a C-shaped white body and darker head. The tail end of the grub often appears dark due to soil it ingests during feeding. Severe feeding damage early in the season may cause the plant to dwarf, become wilted and die. Feeding on root crops in the fall renders them unmarketable.

Period of Activity: European chafers (an annual grub) overwinter as early instar larvae. Peak feeding occurs in April to mid-May. Larvae pupate in the late spring, after which time they are not usually a problem in vegetable crops.

Japanese beetles (an annual grub) overwinter as third instar larvae, which resume feeding in late spring to complete their development. Although the roots of grasses are preferred, larvae will also feed on the roots of vegetables and other crops. Adults emerge in late June and are active through August, feeding on a wide variety of crop and ornamental foliage.

June beetle larvae are present in the soil for 3 years. Feeding is most noticeable in the late spring. However, damage may occur throughout the growing season on root crops.

Thresholds: None have been established. Look for grubs in the crop row, approximately 5 cm below the soil surface. Older pupae of the June beetle larvae may feed on deeper roots, down to 25 cm.

Management Notes: To avoid injury by white grubs, wait 2 or more years before planting vegetables on land that had been planted with grass sod. Where white grubs have been identified prior to planting (or in replant situations), consider planting to a non-host crop, such as beans. Where European chafer or Japanese beetle larvae are present, delaying planting to late spring may eliminate the problem.

OMAFRA Publication AF 141, *Ontario CropIPM*, is an interactive pest management training tool that covers all aspects of insect, disease, weed management, herbicide injury and soil diagnostics for a wide range of vegetable crops. It is available as a CD and online at www.ontario.ca/cropIPM.

Nematodes

Root-lesion, root-knot, sugarbeet cyst nematodes and occasionally the bulb and stem nematode are responsible for most nematode problems in Ontario vegetable crops. A crop may be attacked by the combined action of two or more kinds of nematodes. In some cases, the presence of nematodes aggravates some fungal diseases. For example, the damage caused by root-lesion nematodes together with verticillium wilt of eggplants, tomatoes and potatoes is often worse than the damage caused by either pest alone.

Before deciding upon a management strategy for nematodes, submit a soil sample to a qualified laboratory to determine the type and population of nematodes present. In Ontario, nematode populations in the soil are usually at their highest in May–June and again in September–October. The fall months are a good time to sample soil for nematodes, as the populations are high and management strategies can be developed well in advance of planting the crop the following spring.

See Appendix G, *Diagnostic Services*, on page 240, for sampling and testing information. Table 8–1, *Nematodes Impacting Vegetable Crops in Ontario*, next page, outlines the various treatment thresholds associated with specific nematode species.

For more information, see the OMAFRA Factsheets:

- *Sampling Soil and Roots for Plant Parasitic Nematodes*, Order No. 06-099
- *Bulb and Stem Nematode in Onions and Carrots*, Order No. 00-043

Table 8–1. Nematodes Impacting Vegetable Crops in Ontario

Nematode Species	Crops Affected	Symptoms	Thresholds
Root lesion (<i>Pratylenchus</i> sp.)	Most vegetables	Brownish, scratch-like wounds on plant roots. The lesions are often invaded by secondary pathogens.	tomatoes: 2,000/kg soil ¹ other vegetables: 1,000/kg soil or 50/g dry root
Root-knot (<i>Meloidogyne</i> sp.)	Most vegetables	Galls develop on plant roots. Secondary roots grow around galls, giving the root a hairy appearance. Poor growth, patchy distribution in field.	carrot: zero tolerance root vegetables ² : 500/kg soil (spring sample) other vegetables: 1,000/kg soil
Sugarbeet cyst (<i>H. schachtii</i>)	Beets, spinach, brassica crops and other root crops ²	Stunted plants. Outer leaves wilt, turn yellow prematurely and die. White or brown cysts can be seen on washed roots.	2,000 larvae or eggs/kg of soil, or >250 cysts/kg soil, or 200 eggs/100 g of soil
Bulb and stem (<i>Ditylenchus</i> sp.)	Onions, garlic, leeks, shallots	Twisted and deformed plants, with shorter, thicker leaves (known as "onion bloat"). Splitting and cracking of infected bulbs. On garlic, nematode symptoms are similar to fusarium basal plate rot.	100/kg soil
Pin (<i>Paratylenchus</i> sp.)		Rarely causes crop injury unless present in very high numbers.	5,000/kg of soil

¹ Tomato threshold is for newer, processing varieties with vigorous growth. For older or fresh-market varieties, use 1,000/kg soil as the threshold.

² Root vegetables include parsnips, potatoes, onions and other tuberous crops.

Nematode Control

Caution

Carefully follow the manufacturer's directions for the use of soil fumigants. A permit is required to apply methyl bromide. A permit may be obtained from the Pesticides Control Section, Ministry of the Environment, 135 St. Clair Ave. W., Toronto, M4V 1P5, Tel: 416-323-5095.

When using a fumigant, always follow the instructions on the label carefully regarding rates and application methods and plant-back intervals. Shank-injection of fumigants is preferable to reduce the chance of wind-and-odour drift, runoff or other mishaps. Muck soils often require higher rates.

Fumigate soil either in the fall or in the spring. Note that many fumigants require a 21-day plant back interval to prevent damage to the crop. Soil temperatures affect the performance of fumigants and the length of time between application and planting. Consult each fumigant label for the appropriate soil temperature guidelines. Prior to application, work the soil to a depth of 20–25 cm. The moisture content of the soil must be at a level that would permit good seed germination.

With fall applications, work the soil several weeks before fumigation so that the area is reasonably free from undecomposed crop residue. Do not disturb the soil after sealing until the normal spring cultural operations are started.

After spring fumigation, cultivate the soil thoroughly before planting to aerate and ensure that all traces of fumigant odour have dissipated.

Do not use nematicides containing bromine before planting onion, beet, celery or potato.

See Table 8–2, *Nematode Fumigant Control Recommendations*, opposite page.

Birds

Bird control methods must be in place at least 10 days before the crop becomes attractive for feeding. This is not necessarily 10 days before the crop is ready for harvest. Once the birds have found a food source, it is very difficult to scare them away.

Birds quickly become accustomed to uniform movements and noise patterns. Moving scare devices to new locations regularly will greatly improve control. The randomness of a noise device is much more important than the frequency or level of the noise.

Visual Deterrents

There are several visual bird deterrents available to growers. "Scare-eye" balloons, flashing tape, mirrors and predator-shaped kites are generally not as effective as the noise-making repellants. However, when used in combination, they can improve the efficacy of the acoustic deterrents.

Table 8-2. Nematode Fumigant Control Recommendations

Common Name	Trade Name	Crops	Application	Rate	Notes
1,3 dichloropropene	Telone II	brassicas and cucurbits	broadcast	112 L/ha (mineral soil) 200 L/ha (muck soil)	Apply to cultivated, moist soil only. Seal soil surface immediately after application. Leave soil undisturbed for 7-14 days after application. A longer waiting period may be required if the soil is cold and/or wet.
			rows	65 L/ha (mineral soil) 100 L/ha (muck soil)	
		other vegetables	broadcast	135 L/ha (mineral soil) 200 L/ha (muck soil)	
			rows	65 L/ha (mineral soil) 100 L/ha (muck soil)	
1,3 dichloropropene + chloropicrin	Telone C17	vegetables	broadcast	160 L/ha (mineral soil) 380 L/ha (muck soil)	See above.
			100-cm rows	65 L/ha (mineral soil) 120 L/ha (muck soil)	
chloropicrin	Chloropicrin 100	tomatoes & peppers	broadcast or banded ¹	93 L/ha	Seal immediately after incorporation. Leave soil undisturbed for 10-14 days. Aerate for at least 5 days after cultivation.
		potatoes	banded	55 L/ha	
	Pic Plus	tomatoes & peppers	broadcast or banded ¹	108 L/ha	
		potatoes	banded	64 L/ha	
dazomet	Basamid Granular	eggplant, lettuce, pepper & tomato	seedbeds	3.25-5 kg/100 m ²	Apply to cultivated, moist soil only. Incorporate and seal immediately after application. Leave soil undisturbed for 5-7 days after application when soil is warm or 2-4 weeks if soil is cool. Will not control cyst nematodes. See label for appropriate planting intervals.
metam potassium	Busan 1180	vegetables	seedbed (injection)	430-553 L/ha	Inject into well-cultivated, moist soil only. Seal immediately after incorporation. See the label for sprinkler recommendations. Planting may take place 21 days after treatment if soil is well drained, light-textured and relatively dry and warm.
			field (injection)	231-576 L/ha	
metam sodium	Enfuse M 510	agricultural	broadcast	0.78/30 m ²	Apply evenly over moist, cultivated soil. 7 days after application, rake soil to a depth of 8 cm. Rake again 7 days later to a depth of 5 cm.
	Busan 1020	vegetables	seedbed (injection)	700-900 L/ha	Inject into well-cultivated, moist soil only. Seal immediately after incorporation. See the label for sprinkler recommendations. Planting may take place 21 days after treatment if soil is well drained, light-textured and relatively dry and warm.
			field (injection)	375-935 L/ha	
	Busan 1236	vegetables	seedbed (injection)	511-657 L/ha	
			field (injection)	274-683 L/ha	
	Vapam	vegetables	seedbed (injection)	550-900 L/ha	
			field (injection)	375-935 L/ha	
	Vapam HL	vegetables	seedbed (injection)	410-670 L/ha	
			field (injection)	279-696 L/ha	

¹ Use the following formula to calculate the rate for banded application:

rate for banded application = (product rate x 30)/Row spacing (cm)

Acoustic Devices

There are three principle types of acoustic deterrents. They include propane-fired cannons, electronic sound devices and digital distress calls.

Propane-Fired Cannons

These units are most effective when the timing of the blast is randomized. The cannon should never blast at intervals of less than 3 min. Frequent intervals will only cause the birds to become accustomed to the noise. The efficiency of the device will also be increased if the unit is moved regularly.

In built-up areas, the propane-fired cannon may greatly disturb neighbours. In such a setting, less invasive devices, such as the electronic sound device or digital distress calls, may be more appropriate.

Electronic Sound Devices

These devices make an electronic warbling sound. This noise is irritating to birds and interferes with their sensory system. In short, it makes them edgy and easily scared. These units work particularly well in combination with propane cannons or digital distress calls. Visual repellants may also work well in combination with these devices.

Digital Distress Calls

These electronic devices play bird distress calls over a speaker system. Birds mistake the calls for a warning of danger and abandon the field. The distress call has been known to attract predator birds such as hawks. The presence of hawks flying in the area will also act to deter feeding birds.

Some of these units are programmable, with a selection of different bird calls to chose from. This allows the units to be customized to focus on the species of bird causing the problem. The distress calls are played in a random sequence, with predator calls interspersed.

These units are of particular use in more built-up settings. As they sound like the call of real birds, nearby neighbours are less likely to be disturbed by it.

Deer, Groundhogs, Raccoons and Rabbits

Deer, groundhogs and rabbits can be a serious problem in vegetable plantings, particularly in areas where woodlots or brush surround vegetable fields. Deer and groundhogs will often root for carrots in harvested fields. Raccoons are a serious pest of sweet corn. Trapping groundhogs and raccoons may help reduce the problem.

For more information on deer control, see the OMAFRA website at www.ontario.ca/crops.

9. Crop Management Recommendations

ASPARAGUS

Production Requirements

Asparagus is a long-term vegetable crop. With good management, it will produce viable yields for 15 or more years. Thorough planning is essential for success. Proper field selection and preparation are important for long-term production.

Recommended rotational crops: green manure, alfalfa, soybeans

Do not rotate with: corn, asparagus

Expected Yields

Crop	per acre	per hectare
Provincial average	3,000 lb	3,300 kg
All-male hybrid (established)	>4,000 lb	>4,500 kg

Cultivars

Consult plant and seed suppliers for descriptions of varieties and availability of plants at least 1 year before planting. A list of asparagus crown producers is available on the OMAFRA website at ontario.ca/crops.

Field Selection and Preparation

Plant into well-drained sandy or sandy-loam soils. Avoid fields with a clay sub-soil or other drainage problems. Prior to planting, control perennial weeds. Soil testing is highly recommended to determine fertility levels and pH before planting. Soil pH should range between 6.0 and 6.8. It is considerably more difficult to adjust pH once the crop is established. If possible, use a green-manure crop or livestock manure in the year before planting, to increase soil organic matter. For cover crop options, see Chapter 2, *Soil Management*, on page 21.

Avoid planting asparagus into fields that have previously grown asparagus. Asparagus yields decline over time due to two important *Fusarium* diseases commonly found in asparagus soils. See *Crown Rot* (*Fusarium* sp.), next page, for more information.

Growing Seedlings

Soak seed in 32°C water for 3–4 days. Dry and sow immediately into fertile, well-prepared soil. Plant seed in mid-May or once the ground is prepared and soil temperatures are above 15°C.

To allow for selection of healthy plants, plan to grow extra crowns. One kilogram of good seed should provide enough crowns to plant 1 ha.

Nursery Fields

	Metric	Imperial
Row spacing:	45–60 cm	18–24 in.
In-row spacing:	8–10 cm	3–4 in.
Depth:	2.5–4 cm	1–1.5 in.
Rate:	approximately 11 kg of seed/ha	10 lb/acre

Transplanting and Spacing

Dig the 1-year-old nursery plants in early spring. Discard the weak or small crowns (less than 20 g). Up to one-third of the crowns may be discarded. Plant crowns as soon as possible after digging.

Production Fields

	Metric	Imperial
Row spacing:	1.2–1.5 m	4–5 ft
In-row spacing:	22–30 cm	9–12 in.
Depth (top of crown):	15 cm	6 in.

Fertility

Green manure crops planted in the year prior to asparagus establishment require 30–40 kg N/ha prior to or at seeding. Apply P and K based on crop requirements and soil tests.

Nitrogen

See Table 9–1, *Asparagus Nitrogen Recommendations*, next page.

Table 9-1. Asparagus Nitrogen Recommendations

Timing	Actual N kg/ha
Nursery	75 ¹
New plantings	110 ²
Established plantings	
Pre-harvest	55
Post-harvest	55
Total	110

¹ An additional 50 kg nitrogen/ha may be applied as a side-dress application in August or early September if rainfall was excessive in the summer.

² Broadcast all the recommended nitrogen and potash prior to planting.

Phosphorus

Use a soil test to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, asparagus fields are unlikely to respond to additional phosphate applications. For soils testing less than 61 mg P per L soil (ppm), see Table 1-10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12. Band the phosphate below the crowns at planting.

Potassium

Use a soil test to determine potassium requirements. Where the soil test values are 250 mg K per L soil (ppm) or higher, asparagus fields are unlikely to respond to additional potash applications. For soils testing less than 250 mg K per L soil (ppm), see Table 1-12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Integrated Pest Management

Diseases

RUST

Identification: Look for cream to dark-reddish-brown, oval-shaped, raised pustules on the stems and fronds after harvest. Rust-coloured spores are often easily seen in the centre of the lesions.

Development: The rust fungi overwinter in the field, on crop debris. Infection of growing foliage can occur from April through to early September. Warm weather with heavy dew or light rainfall promotes rust development.

Thresholds: None have been established.

Management Notes: Some asparagus varieties have moderate levels of rust resistance. The fungicides listed in Table 9-2, *Asparagus Disease Control Recommendations*, opposite page, are best used in a preventative program.

Protect plantings as soon as the fronds are about 30 cm high. This usually occurs in late May for new plantings or early July for established ones. Inspect new

plantings for rust as soon as they develop fern. Infected immature fields may act as a source of infection for the commercial plantings. Maintain a 7- to 21-day fungicide spray schedule until late August to protect the fern growth. Thorough coverage of the entire canopy is important.

PURPLE SPOT (STEMPHYLIUM)

Identification: Tan-to-brown, sunken, elliptical lesions with purple edges appear on infected spears, stems and fronds. Infections occurring during harvest reduce the marketability of the crop. Severe summer infections result in the premature defoliation of the fern, which can reduce the following year's yields by up to 52%.

Development: Stemphylium overwinters on asparagus crop residue. During harvest, infections often occur after sand-blasting or high winds have damaged the spears. These microscopic wounds act as a point of entry for the fungi. Once established, stemphylium lesions continue to release spores for the duration of the growing season, infecting new fern as it emerges.

Management Notes: Where infection has been severe, consider destroying infected fern and plant debris, which are sources of overwintering spores. Reduced tillage and the use of cover crops and windbreaks can help reduce the occurrence of sand blasting. See Table 9-2, *Asparagus Disease Control Recommendations*, opposite page. Maintain a 7-21-day preventative fungicide program. Use the shorter spray interval during periods of cool, wet weather or prolonged heavy dewfalls.

CROWN ROTS (FUSARIUM SP.)

Identification: Crown rots caused by *Fusarium oxysporum* and *Fusarium moniliforme* cause yield decline and can limit the productive life of an asparagus planting. *Fusarium*-infected roots turn brown and mushy, limiting the plant's ability to move water and nutrients into the fern. Eventually, the infected plants die.

Development: Both types of *Fusarium* are soil-borne fungi. *F. oxysporum* is found in all soils. Concentrations increase in soils over time as plants become infected. *F. moniliforme* infects both asparagus and corn.

Management Notes: Avoid planting asparagus into fields that have previously grown asparagus. It will take at least 5 years after an asparagus crop for soil levels of *F. oxysporum* to decrease to baseline levels. Do not plant asparagus where corn has been grown in the previous 3 years.

Minimize tillage and use zero-tillage practices where possible. Excessive and deep cultivations can injure crowns and increase fusarium infection.

Table 9-2. Asparagus Disease Control Recommendations
Apply disease control products after harvest.

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
RUST						
DMI (group 3)	myclobutanil	Nova 40 W	340 g in 370 L water	138 g in 33 gal water		Maximum 5 applications/yr.
	propiconazole	Topas 250 E	250 mL in 370 L water	101 mL in 33 gal water	240	Apply at 14-21-day intervals. Maximum 3 applications/yr.
		Mission 418 EC	150 mL in 370 L water	61 mL in 33 gal water	240	
dithiocarbamate (group M3)	zineb	Zineb 80 W	1.1-3.3 kg	0.4-1.3 kg		Apply at 5-10-day intervals. Use high rate on full-grown fern.
	metiram	Polyram DF	2.25-3.25 kg	0.9-1.3 kg		Use high rate on full-grown fern. Apply at 7-10-day intervals. Maximum 4 applications/yr.
PURPLE SPOT (STEMPHYLIUM)						
chloronitrile (group M5)	chlorothalonil	Bravo 500	3.4 L in 100-200 L water	1.4 L in 10-20 gal water	190	Maximum 3 applications/yr. Will also provide rust suppression under low disease pressure conditions. 48-hr re-entry interval.
QoI (group 11)	azoxystrobin	Quadris	0.45-1.1 L	182-445 mL	180	Use high water volumes. Begin application prior to disease development. Use the low rate under low disease conditions. Spray intervals may be lengthened from 7-14 days, under low disease pressure conditions. Maximum 3 applications/yr.

¹ PHI = Pre-Harvest interval (days).

Vigorously growing asparagus plants are less susceptible to crown rots. Take care to avoid stressful growing conditions caused by overpicking, pest pressure, weed competition, soil compaction, drought stress and low fertility.

Asparagus miner larvae may transmit *Fusarium* from the soil into the plant, facilitating infection.

PHYTOPHTHORA

Identification: Phytophthora infections cause soft, water-soaked lesions to develop on emerging shoots at, or slightly below, the soil line. These lesions elongate and turn light brown, causing the infected shoot to collapse and shrivel. The infected side of the spear ceases to grow, causing bending and hooking. Infections are more common during periods of excessive rainfall or in poorly drained fields.

Phytophthora infections on the crown are very similar to fusarium crown rot symptoms. Infections reduce crown vigour and carbohydrate reserves, affecting the long-term productivity of infected fields.

Development: *Phytophthora* is a soil-borne pathogen. It survives as oospores in infected fields for long periods of time. Laboratory studies indicate that the pathogen requires a wound (sand blasting, rain splashing) for infection. *P. asparagi* grows in a range of temperatures from 10°C-25°C, with optimum growth occurring at 25°C.

Management Notes: Avoid planting asparagus in poorly drained soils, or fields with a clay sub-soil. Compaction on sandy-loam soils may reduce drainage and increase the likelihood of infection.

Manage the crop to reduce stress and promote vigorous crown growth. Avoid depleting the crown's carbohydrate reserves through pre-mature harvest or over-harvesting young plantings.

Table 9–3. Asparagus Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
APHIDS						
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	83 mL in 100–200 L water	34 mL in 10–20 gal water	180	Post-harvest only. Maximum 3 applications/yr. 24-hr re-entry interval.
organophosphate (group 1B)	dimethoate ²	Lagon 480 E Cygon 480	2.3 L in 675 L of water	0.9 L in 60 gal of water		Post-harvest only. Maximum 6 applications/yr.
ASPARAGUS BEETLE						
pyrethroid (group 3)	deltamethrin	Decis 5 EC	200 mL in 200–500 L water	81 mL in 20–45 gal water		Apply after cutting only.
	cypermethrin	Ripcord 400 EC UP-Cyde 2.5 EC	86 mL 140 mL	35 mL 57 mL	1 1	Apply when beetles are first observed. 12-hr re-entry interval.
carbamate (group 1A)	carbaryl ²	Sevin XLR	2.5–6.4 L	1–2.6 L	2	Use high water volumes. Do not treat more than once every 3 days.
organophosphate (group 1B)	malathion	Malathion 500 E Malathion 25 W	2.5 L 5.5 kg	1 L 2.2 kg	1 1	
spinosyn (group 5)	spinetoram	Delegate WG	140–280 g	57–113 g	60	Suppression only. Apply at egg-hatch to small larvae. Use higher rates for heavy populations or larger larvae. Maximum 3 applications/yr. 12-hr re-entry.
CUTWORMS						
pyrethroid (group 3)	permethrin	Pounce 384 EC Perm-UP Ambush 500EC	180–390 mL 140–300 mL	73–158 mL 57–121 mL	2 2	Use only the low rate during the cutting season. Use high rate on dry soils. Use high rate on large cutworms. Do not disturb the soil surface for 5 days after treatment. 12-hr re-entry interval.
carbamate (group 1A)	carbaryl ²	Sevin XLR	2.5–6.4 L	1–2.6 L	2	Late-season (climbing) cutworms only. Do not treat more than once every 3 days.

¹ PHI = Pre Harvest Interval (days).

² See Bee Warning, opposite page.

Insects

APHIDS, CUTWORMS, TARNISHED PLANT BUG

For identification and management information on these common vegetable insects affecting asparagus, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–3, *Asparagus Insect Control Recommendations*, this page.

ASPARAGUS BEETLE

Identification: These blue-black beetles with red wing margins and their larvae can reduce asparagus vigour by feeding on the fern during establishment and after harvest. Feeding injury and eggs on the spears at harvest can impact the marketable yields.

Period of Activity: Asparagus beetles overwinter as adults in crop residue and in sheltered areas such as pine windbreaks. Beetle emergence usually coincides with asparagus harvest. First generation larvae are often

active after harvest, during fern establishment. A second generation of adults (and larvae) emerges in late July.

Thresholds:

Eggs:	2 eggs on 10 spears
Larvae:	50% of plants with larvae present or 10% defoliation
Adults:	5%–10% of plants infested

Management Notes: Time field-monitoring activities for the afternoon when the asparagus beetles are more active. See Table 9–3, *Asparagus Insect Control Recommendations*, this page.

Bee Warning

Dimethoate is toxic to bees and should not be used during the bloom period. Carbaryl is especially toxic to bees and should not be used during the fern-growth period. With other insecticides, bee mortality can be reduced if sprays are applied in the late evening when the bees are not foraging. Advise local beekeepers of spraying activity (see *Prevent Bee Poisoning*, on page 53).

ALFALFA PLANT BUG

Identification: The alfalfa plant bug has piercing and sucking mouthparts. As it feeds, it injects toxic saliva into the plant tissue. This causes the spear to wrinkle and become distorted. Under severe feeding, the spear will fail to elongate, dry up and die. Damage is easily confused with *Phytophthora* infections.

Feeding by the alfalfa plant bug may predispose the plant to subsequent *Fusarium* or *Phytophthora* infections.

Period of Activity: Plant bug adults overwinter in hedgerows and plant debris. They emerge and feed in mid-April to late May. Eggs are laid on the stems/petioles of host plants, and 10 days later the nymphs emerge.

Thresholds: None have been established.

Management Notes: Monitor fields for activity at least once a week. Instruct pickers to report any unusual pest activity in the field.

ASPARAGUS MINER

Identification: Asparagus miner larvae create winding tunnels (mines) on the stalks just below the epidermis. The mines are normally found near the base of the plant. The larvae are pure white and range in size from 0.5–5 mm long.

Period of Activity: Miner adults emerge in early June. There are two generations per year, with peak populations normally occurring in mid-June and again in mid-August.

Thresholds: None have been established.

Management Notes: Miners are not usually associated with any significant plant injury or yield loss; however, they transmit *Fusarium* from infected plants to healthy ones.

Mechanical Injury**Hooking**

Bent spears are caused by a physical injury to the spear. Where sandblasting is a problem, spears will "hook"

into prevailing winds. Hooking is also caused by other injuries, including cutworm feeding, inadvertent nicks from cutting knives and abrasions from sharp stones, cultivators, etc.

Fall-seeded cover crops help minimize wind erosion and sand blasting the following spring. Broadcast 100 kg/ha of rye in late August to mid-September. Use a burn-down herbicide in the spring, prior to spear emergence.

Physiological Disorders**Hollow Stem**

This problem tends to be more prevalent in young spears during periods of very rapid growth. Seasons with moderate temperatures and even growth result in a low incidence of hollow stems. Although this problem does not affect the eating quality of the spear, it may reduce marketability.

Harvest

Healthy asparagus plantings can be harvested for about 10–14 days at the beginning of the third season after field setting. For example, if the field is set in the spring of 2010, the first limited harvest would be in the spring of 2012. The harvest season increases by 1–2 weeks per year, up to a maximum of 6–8 weeks.

The length of the harvest season is determined by plant vigour and spear size. Stop harvesting when 75% of the spears are smaller than 1 cm in diameter. If weeds, insects, disease or adverse weather conditions reduce plant vigour, decrease the harvest duration accordingly the following season.

Storage

Freshly harvested asparagus is very perishable and rapidly loses quality. Collect harvested spears from the field, protect them from the sun and move them to cold storage as soon as possible. Store under high humidity at 1°C–2°C.

Hydrocooling is an effective and rapid way of removing field heat from asparagus spears. Under good conditions, asparagus will store for 2–3 weeks.

Fern Disposal

Clip asparagus fern in the fall, leaving 15–20 cm of stubble to catch drifting snow for better crown protection. The stubble can be cut up with a rotary or flail-type mower in early spring. The fern contributes organic matter to the soil and helps prevent early-season wind erosion.

BEANS

Production Requirements

Snap bean and lima bean crops perform well on most soil types, except very heavy clay loams. They require well-drained locations with good fertility. A soil pH of 6.1 to 6.5 is ideal. Harvest snap bean varieties approximately 48–78 days after planting. Lima bean varieties require a slightly longer season. Harvest usually occurs 10–14 days after full bloom.

Recommended rotational crops: sweet corn, tomatoes, peppers and cereal crops

Do not rotate with: soybeans, edible beans, peas, canola, brassica crops

Average Yields

Crop	per acre	per hectare
Processing (green and yellow)	3 tons	6.7 tonnes
Processing (lima)	2 tons	4.4 tonnes
Fresh market (green and yellow)	200 crates	500 crates

Cultivars

Growers and processors are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236. Processing bean growers must grow varieties specified by the processor.

Spacing and Seeding

Sow as shallow as soil moisture permits, usually 2.5–4 cm deep. Lima bean seed may be planted up to 5 cm deep, depending on soil moisture. Snap beans require a minimum soil temperature of 13°C at the time of planting. Lima beans require slightly warmer planting conditions of >15°C.

Planting into cool soil conditions often results in reduced stands due to poor germination, low vigour, and increased seed decay or soil insect pest pressure. Under good soil conditions, germination normally occurs within 6–10 days of planting.

The recommended row spacing and seeding rates vary, depending on the bean type and harvest method. Seed size varies greatly between cultivars. Adjust the seeding rate according to seed count and the expected germination rate. The germination percentage is usually listed on the seed bag.

Table 9–4. Snap and Lima Bean Spacing and Seeding Rates

Crop	Row Spacing cm (in.)	In-Row Spacing cm (in.)	Seeding Rate kg/ha (lb/acre)	Recommended Plant Population plants/ha (plants/acre)
Snap beans (hand harvest)	75–90 (30–36)	5–10 (2–4)	45–90 (40–80)	98,800 (40,000)
Snap beans (machine harvest)	75 (30)	5 (2)	34–78 (30–70)	234,650 (95,000)
Lima beans	75 (30)	5 (2)	108–120 (90–100)	222,300 (90,000)

Increase the seeding rate slightly if seeding in cool soils to compensate for reduced stands. Dark-coloured seeds have better cold soil emergence. See Table 9–4, *Snap and Lima Bean Spacing and Seeding Rates*, this page.

Fertility Nitrogen

Apply 30–40 kg N/ha prior to planting. This may be applied as a preplant broadcast application or banded through the planter, 5 cm below and 5 cm to the side of the seed. Side-dressing of nitrogen is only recommended if foliage shows nitrogen deficiency. Over-application of nitrogen will cause excess leaf growth, resulting in uneven maturity.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 16 mg P per L soil (ppm) or higher, lima and snap bean fields are unlikely to respond to additional phosphate applications. For soils testing lower than 16 mg P per L (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 121 mg K per L soil (ppm) or higher, snap and lima bean fields are unlikely to respond to additional potash applications. For soils testing lower than 121 mg K per L (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Because high rates of banded potassium can damage emerging seedlings, banded potassium should not exceed 60 kg potash/ha.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, on page 17.

Boron

Beans are very susceptible to boron toxicity and should not be grown the year after boron has been applied to previous crops in the field, such as brassica crops, celery or rutabaga.

Manganese

Manganese deficiency may be a problem on beans, especially on soils with pH values above 6.5. Correct the deficiency as soon as it is detected with a foliar manganese spray. Soil application is not recommended for manganese because of the large amounts of fertilizer required. See *Manganese*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management**Diseases****DAMPING-OFF AND ROOT ROT**

For more information on the identification and management of these diseases, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Also see Table 9-5, *Bean Seed Treatments*, next page.

BACTERIAL BLIGHTS**(BROWN SPOT, COMMON BLIGHT, HALO BLIGHT)**

Symptoms: The three bacterial blight diseases are difficult to distinguish in the field. On leaf tissue, look for circular, brown, necrotic lesions, often surrounded by a yellow border. Pod lesions are usually slightly sunken and dark reddish-brown. The pods often become misshapen where the lesions develop.

Development: Common blight usually occurs during warm, humid conditions of 25°C–30°C. Halo blight prefers cooler temperatures in the 16°C–20°C range.

Thresholds: None have been established.

Management Notes: Use only certified, treated seed. The bacterial blight pathogens do not generally overwinter on crop residue in Ontario. Plants damaged by high winds or sand blasting are more susceptible to infection. See Table 9-5, *Bean Seed Treatments*, next page, and Table 9-6, *Snap and Lima Bean Disease Control Recommendations*, on page 75. To be effective, copper fungicides must be applied preventatively.

WHITE MOULD (SCLEROTINIA)

Identification: Dark-green, water-soaked lesions develop on the pods, branches or stems. The lesions enlarge rapidly, encompassing the branches and stems, causing leaves to turn yellow and die. As the crop nears harvest, white, cottony fungal growths develop on pods and stems.

Development: White mould overwinters in the soil as small, black (pea-sized) sclerotia. The initial infection occurs during flowering and early pod development. Temperatures ranging from 20°C–25°C and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil.

Thresholds: None have been established.

Management Notes: Practice a 3–4-year crop rotation away from susceptible crops (cucurbits, edible beans, soybeans, canola, carrots and lettuce). Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions.

See Table 9-6, *Snap and Lima Bean Disease Control Recommendations*, on page 75. Apply a second fungicide spray if high humidity, heavy dews or wet weather conditions persist during bloom.

ANTHRACNOSE

Symptoms: Anthracnose infections first occur as a reddish-brown to purple discolouration along the leaf veins on the leaf underside. Severe infections spread to the upper leaf surface, causing large, irregular-shaped brown lesions to develop.

Pod infections first appear as small brown specks, enlarging into circular, sunken lesions. These lesions often have a pale brown centre and a darker brown margin. Small black spores (*acervuli*) may be visible in the center of the lesion. Under very humid conditions, these spores may turn pinkish.

Development: Anthracnose is spread through infected seed and in crop residue. Wet, windy weather with a relative humidity of at least 92% favours disease development. Temperatures around 17°C are most conducive to spread, although spores can be produced at any temperature from 13°C–26°C.

Thresholds: None have been established.

Management Notes: Use only certified, treated seed. Avoid rotating with other host crops, including dry edible beans and peas. See Table 9-5, *Bean Seed Treatments*, next page.

Table 9-5. Bean Seed Treatments

Active Ingredient(s)	Trade Name	Insects			Seedling Blights					Notes
		Seedcorn Maggots	Wireworm	Potato Leafhopper	Anthraxnose	Phytophthora	Pythium	Fusarium	Rhizoctonia	
thiamethoxam + metalaxyl-M/ fludioxonil	Cruiser 5 FS + Apron Maxx RFC	✓	✓	✓	✓	✓	✓	✓	✓	For use in commercial seed-treatment plants only. See the product labels for rates. Also controls early-season soybean aphids. Use the high rate of Cruiser for wireworm control.
diazinon/captan	Agrox B-2	✓					✓	✓	✓	Seed box treatment. Use 80 g per 25 kg of seed. Do not use on seed previously treated with an insecticide. Plant seeds within 1 month of treatment.
diazinon/captan	Agrox CD	✓					✓	✓	✓	Seed box treatment. Use on seed previously treated with captan or thiram. Use 50 g per 25 kg of seed. Do not use on seed previously treated with an insecticide.
copper hydroxide	Kocide 2000									Suppression of seed-borne bacterial diseases (common blight, halo blight and bacterial brown spot). Use 113 g per 100 kg of seed in 200 mL of water. May delay germination.
fludioxonil/ metalaxyl-M	Apron Maxx RFC				✓	✓	✓	✓	✓	For use in commercial or on-farm seed-treatment equipment only. Use 100 mL per 100 kg of seed.
metalaxyl-M	Apron XL LS					✓	✓		✓	For use in commercial seed-treatment plants only. See the product label for rates.
metalaxyl	Apron FL						✓			For use in commercial seed-treatment plants only. See the product label for rates.
	Allegiance FL						✓			
carbathiin/thiram	VitaFlo				✓		+	+	+	Snap beans only. For use in commercial seed-treatment plants only. See the product label for rates. Do not store treated seed.
thiram	Thiram 75 WP						✓	✓	✓	Seed box treatment. Use 25–30 g per 25 kg of seed.
thiamethoxam	Cruiser 5 FS	✓	✓	✓						For use in commercial seed-treatment plants only. See product label for rates. Request the high rate for wireworm control. Also controls early-season soybean aphid.
imidacloprid	Gaucho 480 FL			✓						For use in commercial or on-farm seed-treatment equipment only. Use 130 mL per 100 kg of seed. Carry-over of Gaucho-treated seed is not recommended.

✓ = registered pest
+ = pest control expected when used to control other labelled pests

✓ = registered pest

+ = pest control expected when used to control other labelled pests

Table 9-6. Snap and Lima Bean Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
BACTERIAL BLIGHT (HALO AND COMMON)						
inorganic (group M)	copper hydroxide	Parasol Flowable	2.3–3.1 L	0.9–1.2 L	1	Make first application when plants are 15 cm (6 in.) high.
		Kocide 2000	1.6–2.3 kg	0.6–0.9 kg	1	
WHITE MOULD (SCLEROTINIA)²						
carboximide (group 7)	boscalid	Lance WDG	560–770 g (use 420 g for grey mould control)	226–311 g (use 170 g for grey mould control)	7	Spray at 20%–50% bloom with a second application 7 days later. Maximum 2 applications/yr. May be tank-mixed with Matador insecticide. 4-hr re-entry interval.
dicarboximide (group 2)	vinclozolin	Ronilan EG	1.0–1.5 kg in min. 220 L water	0.4–0.6 kg in min. 20 gal water	14	Spray at first bloom with a second application 7 days later. Maximum 2 applications/yr.
	iprodione	Rovral	1.5 kg in min. 300 L water	0.6 kg in min. 27 gal water	15	Snap beans only. Spray at 50% bloom. Aerial application permitted. 12-hr re-entry interval.
chlorophenyl (group 14)	dicloran	Botran 75 W	3.25 kg in 800 L water	1.3 kg in 70 gal water	2	Snap beans only. Spray at first bloom. Do not feed treated foliage to livestock.
(group 29)	fluazinam	Allegro 500 F	1 L	0.4 L	14	Spray at 10% bloom with a second spray 7 days later. Maximum 2 applications/yr.
anilino- pyrimidines/ phenylpyrroles (group 9/12)	cyprodinil/ fludioxonil	Switch 62.5 WG	775–975 g	314–395 g	7	Spray at 10%–20% bloom. Repeat after 7 days if the conditions remain favourable for disease development. Use the higher application rate under conditions of high disease pressure. 12-hr re-entry interval.
ANGULAR LEAFSPOT AND RUST						
QoI (group 11)	pyraclostrobin	Headline EC	400 mL	162 mL	7	Snap beans (angular leaf spot control). Maximum 2 applications/yr. 12-hr re-entry interval.
			400–600 mL	162–243 mL	7	Lima beans (rust control). Maximum 2 applications/yr. 12-hr re-entry interval.
PYTHIUM DAMPING-OFF, PHYTOPHTHORA ROOT ROT						
phenylamides (group 4)	metalaxyl-M	Ridomil Gold 480EC	2.3 mL/ 100 m of row ³	0.7 mL/ 100 ft of row		Snap beans only. Make only 1 application/yr at planting.

¹ PHI = Pre-Harvest Interval (days).² For snap beans grown in fields recently affected by sclerotinia white mould.³ 76 cm (30 in.) row spacing, with a 20-cm (8-in.) spray band requires 300 mL/ha (121 mL/acre) of Ridomil Gold 480 EC.**VIRUSES****(BEAN COMMON MOSAIC, BEAN YELLOW MOSAIC, CUCUMBER MOSAIC)**

Symptoms: Leaves develop patches of light- and dark-green discolouration. They often become puckered and twisted. Infected plants become stunted, experience poor seed set and develop misshapen pods. Bean yellow mosaic may also produce bright yellow spots on the leaf tissue.

Development: These viruses are spread by aphids and usually follow periods of high aphid activity.

Management Notes: Chemical aphid controls will not necessarily reduce the amount of viral diseases in the field. See *Viruses (General)*, on page 59. Bean common mosaic is also seed-borne. Buy certified, treated seed and select resistant varieties where possible. Several vegetable crop viruses overwinter in red clover and alfalfa fields. If possible, avoid planting beans near perennial forage crops.

Insects**SEEDCORN MAGGOTS, WIREWORMS, TARNISHED PLANT BUG, APHIDS**

For identification and management information on these common vegetable insects affecting beans, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, Table 9-5, *Bean Seed Treatments*, on page 74, and Table 9-7, *Bean Insect Control Recommendations*, opposite page.

POTATO LEAFHOPPER

Identification: The adult leafhopper is yellow-green, wedge-shaped and approximately 5 mm long. Immature nymphs are smaller and wingless. When disturbed, leafhoppers quickly move forward or sideways. Both the adults and the nymphs feed on beans, causing leaf puckering and browning of the leaf margins (also known as "hopperburn"). Hopperburn is often confused with drought stress.

Period of Activity: Leafhoppers migrate to Ontario in early spring. Initial generations feed on alfalfa before moving into bean crops. Plants are most susceptible to feeding damage prior to bloom. Low levels of feeding on newly emerged seedlings can have a severe impact on yield. Leafhoppers are often found on the undersides of the leaves.

Thresholds:

Adults:	seedling	2 per 33-cm row
	3rd trifoliolate	5 per 33-cm row
Nymphs:	any stage	10 per 100 leaves

Management Notes: See Table 9-7, *Bean Insect Control Recommendations*, opposite page, and Table 9-5, *Bean Seed Treatments*, on page 74. Where beans are planted in the vicinity of an alfalfa field, monitor the crop closely after the hay is cut.

EUROPEAN CORN BORER

Identification: Full-grown corn borer larvae are 2.5 cm in length. They are a greasy white (translucent) colour, with spots and a dark head. Eggs are shiny, white and laid in clusters of 30 that resemble fish scales. Corn borer larvae feed briefly on the leaves but soon begin tunnelling into the stems and pods. Much of the pod damage is internal with only a small entry hole visible on the outside. Grading-out infested pods is very difficult.

Period of Activity: Corn borers overwinter in corn stubble. They become active as soil temperatures consistently exceed 10°C. Southwestern Ontario experiences two generations per year, while the rest of the province has only one. Beans are susceptible to damage from flowering through to harvest.

Thresholds: None have been established.

Management Notes: Where beans follow corn in rotation, consider disking the corn residue in the fall to reduce overwintering borer populations. Borers are most likely to be a pest in snap beans when other host plants are not available (early season, before corn is attractive, or late season, after the corn has dried down). For control options, see Table 9-7, *Bean Insect Control Recommendations*, opposite page.

For more information, see the OMAFRA Factsheet, *European Corn Borer in Sweet Corn and Other Horticultural Crops*, Order No. 97-019.

MEXICAN BEAN BEETLE AND BEAN LEAF BEETLE

Identification: Mexican bean beetle adults are coppery-red, oval and approximately 6 mm in length with 16 black spots on the wing casings. They resemble ladybugs. The larvae are yellow with rows of long, black-tipped spines along their backs. Both the adults and the larvae feed on leaf tissue.

Bean leaf beetle adults are 5 mm in length with four black spots on the wing covers. A small, black triangle is visible at the base of the head. The colour varies from yellow to tan or red. Bean leaf beetle larvae complete their development in the soil, feeding on roots.

Period of Activity: Mexican bean beetle adults emerge from overwintering sites (grassy fencerows and wooded areas) in early May. Eggs are laid, and feeding continues for approximately 1 month. Mexican bean beetles complete one to two generations per year.

Bean leaf beetles complete only one generation. The adults emerge in late April and may be found feeding on early snap bean plantings. Egg laying occurs until late June, with the larvae feeding on the roots for up to 30 days before the adults emerge.

Thresholds: Chemical controls may be required if leaf defoliation exceeds 20% prior to bloom and 10% during pod-fill. See Figure 9-1, *Defoliation Chart for Soybean Leaf-Feeding Insects*, on page 78. Excessive defoliation from these beetles will result in early maturity and yield losses.

Management Notes: See Table 9-7, *Bean Insect Control Recommendations*, opposite page. Consider using border sprays to control the beetles as they move out of the fencerow.

Table 9-7. Bean Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
LEAFHOPPERS, MEXICAN BEAN BEETLES, TARNISHED PLANT BUG, APHIDS						
pyrethroid (group 3)	lambda- cyhalothrin ²	Matador 120 EC ²	83 mL	34 mL	7	Snap Beans. Leafhoppers, tarnished plant bugs and aphids. Maximum 3 applications/yr. Aerial application permitted. 24-hr re-entry interval.
					14	Lima Beans. Leafhoppers, tarnished plant bugs and aphids. Maximum 3 applications/yr. Aerial application permitted. 24-hr re-entry interval.
		Silencer 210 EC ²	83 mL	34 mL	14	Maximum 3 applications/yr. Aerial application permitted. 24-hr re-entry interval.
organophosphate (group 1B)	dimethoate ²	Cygon 480 ²	0.7–1 L	0.3–0.4 L	7	Maximum 3 applications/yr.
		Lagon 480 ²	0.7–1 L	0.3–0.4 L	7	Snap beans only. Aerial application permitted. Maximum 3 applications/yr.
	malathion	Malathion 500 E	1.5–2.75 L	0.6–1.11 L	3	Will not control tarnished plant bug.
	naled	Dibrom	1.1–2.2 L	0.4–0.9 L	4	Lima beans only. Aphid control only. Aerial application permitted. Do not apply when temperature is >32°C. 48-hr re-entry interval.
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–1.5 L	0.5–0.6 L	5	Mexican bean beetle. Use low rate on young plants.
			2.5 L	1 L	5	Potato leafhopper.
chlorinated cyclodiene (group 2A)	endosulfan ²	Thiodan 4 EC ²	1.5–2.5 L	0.6–1 L	2	Snap beans only. Potato leafhopper and Mexican bean beetle. Also controls green cloverworm.
		Thionex 50 WP ²	1.1–1.5 L	0.4–0.6 L	2	
BEAN LEAF BEETLE						
pyrethroid (group 3)	lambda- cyhalothrin ²	Matador 120 EC ²	83–233 mL	34–94 mL	7	Snap Beans. Maximum 3 applications/yr. 24-hr re-entry interval.
					14	Lima Beans. Maximum 3 applications/yr. 24-hr re-entry interval.
EUROPEAN CORN BORER						
pyrethroid (group 3)	lambda- cyhalothrin ²	Matador 120 EC ²	83 mL	34 mL	7	Snap beans. Apply before corn borer larvae tunnel into the stalk or pods. Maximum 3 applications/yr. 24-hr re-entry interval.
					14	Lima beans. Apply before corn borer larvae tunnel into the stalk or pods. Maximum 3 applications/yr. 24-hr re-entry interval.
		Silencer 210 EC ²	83 mL	34 mL	14	Maximum 3 applications/yr. Aerial application permitted. 24-hr re-entry interval.
	permethrin	Pounce 384 EC	260 mL	105 mL	7	Snap beans only. Aerial application permitted. Maximum 2 aerial applications/yr. 12 hour re-entry interval.
		Perm-UP				
		Ambush 500 EC	200 mL	81 mL	7	Snap beans only.
spinosyn (group 5)	spinosad	Success 480 SC	83 mL	34 mL	3	Snap beans only. Use only on small larvae and low infestations. Maximum 2 applications/yr. Maintain a spray pH of 6 or greater.
		Entrust 80 W	50 g	20 g	3	
biological (group 11)	<i>Bacillus thuringiensis</i>	Bioprotec CAF	2.8–4.0 L	1.1–1.6 L	1	Snap beans only. Maximum 4 applications/yr. Allow 5–10 days between applications.
carbamate (group 1A)	methomyl	Lannate TNG	550 g	223 g	7	24-hr re-entry interval.
CUTWORMS						
pyrethroid (group 3)	lambda- cyhalothrin ²	Matador 120 EC ²	83 mL	34 mL	14	Apply in the late evening or at night. Maximum 3 applications/yr. 24-hr re-entry interval.
		Silencer 210 EC ²				
SLUGS						
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Apply to moist soils. Use higher rates on severe infestations.
SPIDER MITE						
diphenylethane (group 3)	dicofol ²	Kelthane 50W ²	1.0–1.25 kg	0.4–0.5 kg	7	Make only 1 application/yr. Use high rate on larger plants.

¹ PHI = Pre-Harvest Interval (days).² Do not graze or feed treated foliage to livestock.

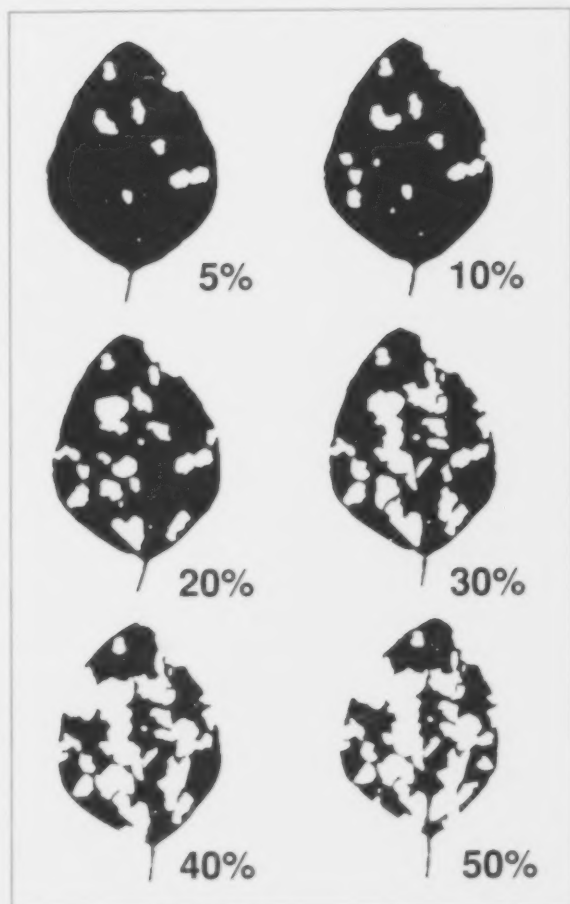


Figure 9-1. Defoliation Chart
for Soybean Leaf-Feeding Insects

Source: University of Illinois and Purdue University, 1982.

TWO-SPOTTED SPIDER MITES

Identification: Adult mites are approximately 0.5–1 mm in length and barely visible to the naked eye. They are a translucent yellowish colour with two dark spots on the sides of their abdomen. Spider mites use sucking mouth parts to feed on individual cells. Injury first appears as yellowing or a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress. Mites are commonly found on the lower leaf surface, surrounded by a fine silky web.

Period of Activity: Spider mite activity is most common in hot, dry conditions. They often move into bean crops following wheat harvest.

Thresholds: High populations prior to pod fill are the greatest cause for concern. Spray if there are 4 or more mites per leaf or one severely damaged leaf per plant.

Management Notes: Heavy rain or overhead irrigation often reduces mite levels to below threshold levels. See Table 9–7, *Bean Insect Control Recommendations*, previous page.

Physiological Disorders

Bronzing

Bronzing is a physiological disorder. It is caused by high levels of atmospheric ozone associated with air pollution. A bronze-coloured stipple develops on the pods and the upper surface of the leaves. Pod and seed set are usually reduced, and the plants age prematurely. Dry beans and limas appear more sensitive than snap beans; cultivars within these types differ in susceptibility. Be careful not to confuse air pollution injury with spider mite feeding.

Storage

Store fresh-market snap beans at 7°C–10°C and a relative humidity of 95%. Under good conditions, beans store for 7–10 days. If possible, keep lima beans at slightly lower temperatures.

BEETS, TABLE

Production Requirements

Beets perform best on a well-drained, loamy soil. They can also be grown successfully on well-drained muck soils. Emergence will be poor on heavy soils or those prone to crusting. A soil pH of 6.8–7.8 is ideal. Beets require 55–80 days from seeding to harvest for fresh market and 70–110 days for processing crops.

Beets are frost tolerant. The best colour and quality are obtained when they are grown during cool temperatures of 13°C–21°C. Heavy rains following a hot, dry period or extended periods of high temperature will cause poor colour.

Recommended rotational crops: beans, cereal crops, corn, cucurbits, eggplant, peas, peppers, potatoes, soybeans, tomatoes

Do not rotate with: sugarbeets, brassica crops

Average Yields

Crop	per acre	per hectare
Fresh-market beets	400–600 23-kg bags	1,000–1,500 23-kg bags
Processing beets	15–20 tons	34–45 tonnes

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236. For beets grown for processing, the processor will determine the varieties to be grown.

Field Seeding and Spacing

For a continuous supply of beets for bunching, sow seed at 2-week intervals, from early April to the end of July. Early processing crops can also be seeded in early spring. For storage and late processing crops, sow about 10 weeks before late-fall harvesting. Seed will not germinate at temperatures lower than 4.5°C. The optimum germination temperature is from 10°C–29°C.

If necessary, thin plants 5–8 cm apart. No thinning is required when seeders are adjusted to ensure a stand of 32–40 plants/m of row.

	Metric	Imperial
Row spacing:	30–40 cm	12–16 in.
Rate:	7 kg/ha	6 lb/acre
Depth:	1.2–2.0 cm	½–¾ in.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Broadcast and incorporate all the recommended preplant nitrogen along with the recommended potash and phosphate. On mineral soils, apply the remainder of the nitrogen as a side-dress application. See Table 9–8, *Table Beet Nitrogen Recommendations*, this page.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, beets grown on both mineral and muck soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, beets grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Table 9–8. Table Beet Nitrogen Recommendations

Soil	Actual N kg/ha
Mineral Soils	
Preplant	65
Side-dress	45
Total	110
Muck Soil	
Preplant	40

Table 9–9. Table Beet Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL/ 100 kg seed	damping-off (<i>Pythium</i> and <i>Phytophthora</i>)	For use in commercial seed-treatment plants only.
Maxim 480 FS	fludioxonil	5.2–10.4 mL/ 100 kg seed	damping-off (<i>Fusarium</i> , <i>Rhizoctonia</i> , <i>Aspergillus</i> and <i>Penicillium</i>)	For use on imported seed only.
Thiram 75 WP	thiram	90 g/ 25 kg seed	damping-off, seed decay	Seed box treatment.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Boron

Boron deficiency shows up as a corky, dark discolouration of internal tissues. It is most likely to occur on high pH (alkaline) soils after prolonged hot, dry periods. See *Boron*, on page 18, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Manganese

Deficient plants show marked yellowing between the leaf veins; the veins themselves remain green. To correct a deficiency, spray with manganese sulfate. See *Manganese*, on page 18, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases affecting table beets, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Also see Table 9–9, *Table Beet Seed Treatments*, this page.

CERCOSPORA LEAF SPOT

Identification: Look for numerous small, circular lesions with a dark-brown to purplish halo on the leaves. Small black dots may be seen with a magnifying lens in the centre of the lesions. The centres may turn grey and fall out, leaving a ragged appearance. This disease can lead to defoliation and reductions in yield.

Leaf lesions reduce the marketability of fresh beets sold with tops.

Development: *Cercospora* is present from mid-July through early September. Air temperatures above 24°C with extended periods of leaf wetness due to rain, dew or fog are favourable for *cercospora* development.

Thresholds: None have been established. Monitor for the appearance of leaf lesions and apply a fungicide at the first indication of infection.

Management Notes: If monitoring indicates a need, apply fungicide as indicated in Table 9–10, *Table Beet Disease and Insect Control Recommendations*, opposite page.

POCKET ROT, ROOT ROT (RHIZOCTONIA)

Identification: Symptoms vary from cankers on the lower petioles and crowns to root rot of beets.

Development: This disease is more severe when sustained wet conditions have occurred. It is most active at temperatures of 25°C–33°C.

Thresholds: None have been established.

Management Notes: Avoid throwing soil onto beet crowns while cultivating. Rotate with grain crops. Management practices that improve drainage and soil structure should reduce disease severity.

Insects

WIREWORMS, CUTWORMS, APHIDS

For identification and management information on these common vegetable insects affecting table beets, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–10, *Table Beet Disease and Insect Control Recommendations*, opposite page.

LEAFMINERS

Identification: Look for the presence of tunnels or “mines” inside the leaves. Eggs are laid on the underside of leaves.

Development: Throughout the season.

Table 9–10. Table Beet Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI¹	Notes
CERCOSPORA LEAF SPOT						
inorganic (group M1)	copper sulfate	Copper 53 W	4.0 kg	1.6 kg	1	
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	227–340 g	3	Maximum 2 sequential applications. Maximum 3 applications. 72-hr re-entry interval (hand-thinning).
RHIZOCTONIA						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/ 100 m of row	1.2–1.8 mL/ 100 ft of row	40	One application/yr, applied in-furrow at planting or banded within 30 days of emergence.
CUTWORMS						
pyrethroid (group 3)	permethrin	Pounce 384 EC	180–390 mL	73–158 mL		Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application. Use high rate on large larvae, dry soils or muck soils. 12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC	140–300 mL	57–121 mL		
APHIDS						
organophosphate (group 1B)	dimethoate	Cygon 480	700 mL	283 mL	12	Beet greens only.
	diazinon	Diazinon 500 E	1.1 L	0.45 L	14	Control of aphids with diazinon has been inconsistent in many areas.
		DZN 600 EW	915 mL	370 mL	14	
	malathion	Malathion 25 W	2.25–5.5 kg	0.9–2.2 kg	7	Control of aphids with malathion has been inconsistent in many areas.
		Malathion 500 E	1.1–2.75 L	0.45–1.1 L	7	
LEAFHOPPERS						
organophosphate (group 1B)	dimethoate	Cygon 480	700 mL	283 mL	12	Beet greens only.

¹ PHI = Pre-Harvest Interval (days).

Thresholds: None have been established. Scout for mines or for eggs on the underside of leaves.

Management Notes: Leafminer control is usually required only for bunching beets, where damage-free tops are required.

Nematode Control

To avoid damage from sugar-beet cyst nematode, do not plant beets following rhubarb, spinach, beets or cruciferous crops. Rotation to non-host crops for 4–5 years will significantly reduce populations of this nematode. See *Nematodes*, on page 63.

Harvest and Storage

Harvest of early plantings begins in mid-summer and can continue through fall frosts for late crops. Harvest must be completed before a hard freeze.

Mature, topped beets may be stored for 4–6 months at close to 0°C and 98%–100% relative humidity. Do not allow the beets to freeze.

BRASSICA CROPS

BROCCOLI, BRUSSELS SPROUTS, CABBAGE, CAULIFLOWER, HORSERADISH, KALE, KOHLRABI AND SPECIALTY VEGETABLES, INCLUDING CHINESE CABBAGE, CHINESE MUSTARD, BROCCOLI RAAB, COLLARDS, MIZUNA, MUSTARD GREENS, MUSTARD SPINACH AND RAPE GREENS

Production Requirements

Brassica crops are cool-season vegetables. They grow best in sandy loam soils at a pH of 6.5. They perform best at moderate temperatures and can withstand mild frosts. Cauliflower is the most sensitive to adverse weather. Brassica crops have a relatively high moisture requirement. Even moderate drought stress at any time during the growing season may cause significant reductions in growth, yield or quality. Dry growing conditions may result in tipburn, bolting and/or buttoning.

Heading brassica crops (e.g., broccoli, Brussels sprouts, cabbage and cauliflower) mature in 70–120 days. Most kale and kohlrabi mature in 50–55 days. Specialty brassica crops maturity is crop specific.

Recommended rotational crops: beans, celery, corn, onions, peas, peppers, tomatoes, and cereal crops

Do not rotate with: other brassica crops, including canola

Average Yields

Crop	per acre	per hectare
Broccoli (12, 14 or 18 bunches/case)	260–320 cases	650–800 cases
Brussels sprouts	10,000–12,000 lb	11,000–13,500 kg
Cabbage (12 or 16 heads/case)	650–1,000 cases	1,500–2,500 cases
Cauliflower (6, 9, 12 or 16 heads/case)	450–700 cases	1,000–2,000 cases
Horseradish	6,750–10,800 lb	7,500–12,000 kg
Kale	40,000 lb	45,000 kg
Kohlrabi	12,000–16,000 lb	13,500–18,000 kg

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under Ontario growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding, Spacing and Establishment

Brassica seeds will germinate at temperatures as low as 4°C. However, they develop best at temperatures between 21°C–24°C. Direct seeding in the field is possible for late summer and fall heading brassica crops although this practice is not widely used in Ontario. Consider establishing transplants from plug trays as a method of promoting uniform size and maturity.

Despite the higher initial cost of plug plants, the benefits include better seed use efficiency and reduced transplanting and thinning costs. Plug-raised plants also establish quickly and provide a more uniform and vigorous stand compared to bare-root transplants. See Table 9–11, *Brassica Crop Spacing and Seeding Rates*, opposite page.

Fertility

Starter Solution

If no insecticide is being added to the planting water, use a starter solution high in nitrogen such as 20-20-20 at 1 kg/200 L and apply 0.2–0.3 L per plant. Under high temperatures or in dry sandy soils, use half the recommended rate (in the same volume of water) to reduce the risk of crop injury under these growing conditions.

Table 9-11. Brassica Crop Spacing and Seeding Rates

Crop	Row Spacing ¹		In-Row Spacing		Seed Required	
	cm	in.	cm	in.	g/ha	g/acre
Broccoli ² , early cabbage	60–75	24–30	30–45	12–18	300–350	120–140
Late cabbage, cauliflower and Brussels sprouts ³	75–90	30–35	45–60	18–24	300–350	120–140
Horseradish	75–90	30–35	40–60	16–24	300–350	120–140
Kale ⁴	70–80	28–32	thinned to 30 cm	thinned to 12 in.	300–350	120–140
Kohlrabi ⁴	70–80	28–32	thinned to 10 cm	thinned to 4 in.	300–350	120–140
Nappa cabbage ⁴	45–60	18–24	25–30	10–12	100–220	40–88
Bok choy ⁴	45	18	15–20	6–8	336	135
Chinese broccoli ⁴	30–45	12–18	thinned to 5–10 cm	thinned to 2–4 in.	900	360

¹ Grow new, more compact hybrids at closer spacings than the traditional cultivars.

² Increased plant spacings for broccoli crops that will be harvested during the hot, humid weather of late August to early September.

³ Close square spacing of 60 x 60 cm or even 53 x 53 cm is required to improve the uniformity of Brussels sprouts that are grown for once-over harvesting and/or where smaller sprouts are required for freezing.

⁴ Direct seeded.

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen application. (See Table 1-8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1-9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Broadcast and incorporate the recommended preplant nitrogen with all the required potash and potassium. Side-dress the remaining nitrogen approximately 3 weeks after field setting. See Table 9-12, *Brassica Crop Nitrogen Recommendations*, this page.

Table 9-12. Brassica Crop Nitrogen Recommendations

Soil Type	Actual N kg/ha		
	Broccoli, Cauliflower, Brussels Sprouts	Cabbage	Horseradish, Kale, Kohlrabi
Mineral Soils¹			
Preplant	100	130	80
Side-dress ²	30	40	30
Total	130	170	110
Muck Soils			
Preplant	70	100	70
1st side-dress	30	30	30
2nd side-dress	30	30	30
Total	130	160	130

¹ If rainfall is excessive, an additional 40 kg of nitrogen/ha may be side-dressed on sandy soils.

² 3 weeks after field setting.

Phosphorus

Soil tests are required to determine phosphorus requirements. Where soil test values are 61 mg P per L soil (ppm) or higher, brassica crops are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), see Table 1-10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where soil test values are 181 mg K per L soil (ppm) or higher, brassica crops are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L (ppm), see Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1-12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

BORON DEFICIENCY

Boron deficiency has been shown to cause hollow stem in broccoli, but not all hollow stem is caused by boron deficiency. Use caution when applying boron. Many rotational crops are sensitive to high levels of boron in the soil. See *Boron*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Table 9–13. Brassica Crop Seed Treatments

Trade Name	Active Ingredient	Rate	Pests Controlled	Notes
Maxim 480 FS	fludioxonil	5.2–10.4 mL/ 100 kg of seed	damping-off (<i>Fusarium</i> , <i>Rhizoctonia</i> , <i>Aspergillus</i> and <i>Penicillium</i>)	For import use only. Not for domestic commercial or on-farm seed treatment.
Apron XL LS	metalaxyl-M	20–40 mL/ 100 kg of seed	damping-off (<i>Pythium</i> and <i>Phytophthora</i>)	
Thiram 75 WP	thiram	90 g/ 25 kg of seed	seedling blight and damping-off	Seed box treatment. For use on broccoli, Brussels sprouts, cabbage, cauliflower and mustard.

MOLYBDENUM DEFICIENCY (WHIPTAIL)

Molybdenum deficiency causes whiptail in cauliflower, broccoli and Brussels sprouts. Molybdenum can be applied in the transplanting water at the rate of 30–40 g of sodium molybdate per 100 L of water, each plant receiving 0.3 L of this solution. See *Molybdenum*, on page 19, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. For more information, see *Plant Tissue Analysis*, on page 5.

Integrated Pest Management

For further information on brassica crop pest management, see the following OMAFRA publications:

- Ontario CropIPM, Order No. AF141
- Integrated Pest Management for Crucifers in Ontario, publication 701
- OMAFRA Factsheet *Fungal Diseases of Cruciferous Crops*, Order No. 85-043
- OMAFRA Factsheet *Bacterial Diseases of Cruciferous Crops*, Order No. 86-046
- OMAFRA Factsheet *Black Rots of Crucifer Crops*, Order No. 02-025

Diseases**DAMPING-OFF AND ROOT ROTS**

For identification and management information, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

To manage damping-off and root rots, see Table 9–13, *Brassica Crop Seed Treatments*, this page, and Table 9–14, *Brassica Crop Disease Control Recommendations*, opposite page.

DOWNY MILDEW

Identification: Symptoms appear as yellow spots on the upper leaf surface with corresponding greyish-white

fungal growths on the underside. Infected cauliflower curds develop dark-grey spots. When the curds are cut open, grey streaks are evident beneath the florets. In broccoli, grey streaks occur beneath the heads. This discolouration leads back to the main stem. Cabbage heads develop numerous black spots.

Development: Infection occurs at any growth stage. Cool temperatures of 10°C–15°C and prolonged periods of leaf wetness, dew or fog favour disease development. This fungus overwinters in seed and on infected plants. Downy mildew fungi survive for at least 1 year in the soil and 2 years in infected seed.

Thresholds: None have been established.

Management Notes: Plant into well-drained soil. Avoid excessive use of overhead irrigation. Follow a 2-year rotation with non-host crops. Resistant broccoli varieties are available.

If weather conditions favour disease development, apply one of the preventative fungicides listed in Table 9–14, *Brassica Crop Disease Control Recommendations*, opposite page.

FUSARIUM WILT (CABBAGE YELLOWS)

Identification: Infected seedlings turn yellow and die within 2–4 weeks. The lower leaves are the first affected. The yellowing is often more intense on one side of the plant.

Development: Fusarium wilt is soil-borne. Plants may be affected at any time during growth. The disease enters the plant through young roots or through wounds in older roots. Fusarium wilt is a warm-weather disease and will not develop below 16°C or above 32°C.

Management Notes: Use certified disease-free seed and resistant cultivars (if available). Potassium deficiency may further aggravate this disease.

Table 9-14. Brassica Crop Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
GREENHOUSE TRANSPLANT DISEASE CONTROL (DAMPING-OFF AND ROOT ROT)						
phthalamide (group M4)	captan	Maestro 80 DF	1.25 kg/1,000 L of water Apply 50–85 L of solution per 100 m ² (1,076 ft ²)			Soil drench treatment. 48-hr re-entry interval.
dithiocarbamate (group M2)	oxine benzoate	No-Damp		10 mL/ L of water		Damping off only. Soil treatment.
DOWNY MILDEW, ALTERNARIA, WHITE ROT						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.5–4.8 L	1–1.9 L	7	Not on horseradish, kale or kohlrabi. 48-hr re-entry interval.
phosphonate (group 33)	fosetyl-al	Aliette WDG	2.25–3.12 kg	0.9–1.3 kg	7	Broccoli and bok choy only. Downy mildew only. Maximum 5 applications/yr. 12-hr re-entry interval.
inorganic (group M1)	copper sulphate ²	Copper 53 W ²	4.0 kg	1.6 kg	1	Broccoli, cabbage, cauliflower and Brussels sprouts only.
dithiocarbamate (group M3)	zineb	Zineb 80 W	1.1–3.3 kg	0.4–1.3 kg	7	Not on horseradish, kale or kohlrabi.
dicarboximide (group 2)	iprodione	Rovral	3 kg	1.2 kg	7	Alternaria only. Storage cabbage. ³ 12-hr re-entry interval.
					5	Alternaria only. Cauliflower. ³ 12-hr re-entry interval.
QoI (group 11)	pyraclostrobin	Cabrio EG	0.56–1.1 kg	226–445 g	3	Alternaria & cercospora control. Horseradish only. Maximum 3 applications/yr. Apply no more than 2 sequential applications. 3-day re-entry interval (hand-thinning).
carboxylic acid amides) (group 40)	mandipropamid	Revus	400–600 mL	161–242 mL	1	Downy mildew. Maximum of 4 applications/yr. The use of a non-ionic adjuvant (0.125% v.v) is recommended.
		Serenade ASO	8–15 L	3.2–6 L	0	Suppression of downy mildew. Begin applications when conditions are conducive to disease development. Repeat at 7–10-day intervals.
			12–24 L	4.8–9.7 L	0	Suppression of white rot. Begin applications when conditions are conducive to disease development. Repeat at 7–10-day intervals.
POWDERY MILDEW						
phenylpyrroles + anilino- pyrimidines (group 12 + 9)	cyprodinil + fludioxonil	Switch 62.5 WG	775–975 g	313–394 g	7	Mustard/turnip greens and cabbage only. Maximum 3 applications/yr. Do not make more than 2 sequential applications. Use high rate for heavy disease pressure. 12-hr re-entry.
RHIZOCTONIA						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/ 100 m of row	1.2–1.8 mL/ 100 ft of row	40	Horseradish only. One application/yr; applied in-furrow at planting or banded soon after emergence.
CLUBROOT (TRANSPLANT TREATMENTS) ⁴						
chlorophenyl (group 14)	quintozene	Quintozene 75 WP	1–3 kg/400 L water 250–350 mL per plant			Provide good agitation during application.
pyridinamine (group 29)	fluazinam	Allegro 500 F	50 mL/100 L water Apply 100 mL per plant		65	Head and stem brassica (e.g., cabbage, broccoli) transplant treatment. Apply immediately after transplanting.
					30	Leafy brassica greens (e.g., Chinese cabbage, mustards) transplant treatment. Apply immediately after transplanting.
					65	Head and stem brassica, leafy brassica greens pre- transplant treatment. Apply solution in a minimum band of 25 cm along the row and incorporate to a depth of 15–20 cm. If using transplants, plant the seedlings into the treated band or make a broadcast application prior to bed formation.

¹ PHI = Pre-Harvest Interval (days).² Fixed copper may be phytotoxic to cauliflower.³ Apply Rovral on storage cabbage 7–14 days prior to harvest and on cauliflower 1–2 days prior to tying.⁴ Chemical control of clubroot is inconsistent.

CLUBROOT

Identification: The first noticeable symptom of clubroot is the wilting, stunting and yellowing of plants in patches in the field. When these plants are pulled, a characteristic thickening of the infected root tissue is evident. Severely distorted roots have difficulty absorbing water and minerals from the soil.

Development: Clubroot is a soil-borne disease. It affects all members of the brassica family. Clubroot is present in the soil in most areas of the province. Once in a field, the resting spores persist for many years.

Management Notes: Control brassica weeds and rotate with non-brassica crops. Maintain a soil pH of 7.2 or higher. Clubroot spores need free water to move in the soil. Plant into well-drained soils. Muck soils are at a high risk of clubroot infection. Grow only short-season (less than 6 weeks) brassica crops on high-risk soils. See Table 9–14, *Brassica Crop Disease Control Recommendations*, previous page.

BLACK ROT

Identification: V-shaped, yellow lesions develop along the leaf margins. As the lesions expand, the tissue turns brown, and the veins become blackened.

Development: Black rot is spread rapidly during warm, humid weather. Once in the soil, the bacteria spread by splashing rain and wind. Bacteria enter plants through wounds or natural openings at the leaf margins called hydathodes.

Management Notes: Use certified disease-free seed and/or hot-water-treated seed. Discard all diseased or unhealthy transplants before planting. Follow a 2–3-year crop rotation to non-brassica crops and control all brassica weeds.

ALTERNARIA (BLACK LEAF SPOT)

Identification: Small, yellowish lesions develop on older leaves. As the spots expand, they resemble a “target” with concentric light and dark areas. On cauliflower and broccoli, black, sunken spots develop on individual florets. Infections on cabbage heads range in size from pinpoints to several centimetres in diameter.

Development: Alternaria is both seed-borne and spread by wind throughout the summer season. Cool, humid conditions favour black spot development.

Thresholds: None have been established.

Management Notes: Adequate air circulation will reduce humid conditions in the canopy. Ensure

that cabbage heads are free of alternaria before going into storage. If this disease is present in the field, protect the plants with a fungicide prior to harvest. See Table 9–14, *Brassica Crop Disease Control Recommendations*, previous page.

WHITE LEAF SPOT

Identification: Infected leaves exhibit scattered, circular, white-to-tan spots. These spots become white and papery, enlarging as the disease develops. Heavily infected plants may show severe spotting, with some defoliation. On waxy-leafed brassica crops, the lesions take on a branching shape.

Development: White spot persists from season to season on leaf litter. Cool temperatures from 12°C–18°C, rainfall and long periods of humidity support disease development. Spores spread by wind, splashing rain and irrigation. The disease does not spread in warm weather.

BACTERIAL SOFT ROT

Identification: Infected leaf or head tissue often takes on a tan colour, becoming moist and mushy and developing a foul odour.

Development: Soft rot spreads rapidly in warm, humid conditions. Insect damage may predispose plants to soft-rot infection.

Management Notes: Plant into well-drained soils and maximize air flow through the plant canopy. Once the disease is identified in a field, avoid overhead irrigation. Rotate with less-susceptible crops (cereals or corn) and control chewing insects. In storage, temperatures below 4°C inhibit the development of new infections. Practice good storage sanitation (see *Storage Sanitation*, on page 50).

Insects

APHIDS, CUTWORMS, SLUGS, TARNISHED PLANT BUG
For identification and management information on these common vegetable insects affecting brassica crops, see Chapter 8, *General Pests of Vegetable Crops*, on page 59. See also Table 9–15, *Brassica Crop Aphids, Cutworms, Slugs and Two-Spotted Spider Mites Control Recommendations*, opposite page.

Table 9-15. Brassica Crop Aphids, Cutworms, Slugs and Two-Spotted Spider Mites Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
APHIDS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	23–35 g	7	See the label for a complete list of all brassica crops, including specialty brassicas. Maximum 5 applications/yr. Alternate sprays with other insecticide families. 12-hr re-entry interval.
	imidacloprid	Admire 240 F	730 mL	295 mL	21	Side-dress application. Inject to a depth of 2.5 cm, 5–10 cm to the side of each row. Maximum 1 application/yr. 24-hr re-entry interval.
			200 mL	81 mL	7	Foliar application. Do not make a foliar application following a soil application. Maximum 2 applications/yr. 24-hr re-entry interval.
tetronic acid derivative (group 23)	spirotetramat	Movento 240 SC	220–365 mL	89–147 mL	3	Most effective on young stages of pest development. Slow activity; control may not be apparent for 2–3 weeks.
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	28	Cabbage, Brussels sprouts, cauliflower only. Maximum of 4 applications/yr. 12-hr re-entry interval.
	dimethoate	Cygon 480	0.7–1.0 L	0.28–0.4 L	4	Cauliflower, broccoli.
					7	Kale. Low rate only.
					21	Brussels sprouts. Use low rate on Brussels sprouts.
		Lagon 480 E	0.6–1.0L	0.24–0.4 L	7	Chinese broccoli, Chinese cabbage, bok choy.
					4	Broccoli and cauliflower.
					21	Brussels sprouts.
	methamidophos	Monitor 480	1.1–2.3 L	0.4–0.9 L	7	Cabbage, cauliflower. 48-hr re-entry interval.
					14	Broccoli, Brussels sprouts. 48-hr re-entry interval.
	naled	Dibrom	1.1 L	0.4 L	4	Broccoli, Brussels sprouts, cabbage, cauliflower and kale. 48-hr re-entry interval.
1.1–1.65 L			0.4–0.7 L	4	Mustard greens. Maximum 3 applications/yr. 48-hr re-entry interval.	
CUTWORMS						
pyrethroid (group 3)	cypermethrin ²	Ripcord 400 EC ²	175 mL	71 mL	21	Cabbage, cauliflower, broccoli and Brussels sprouts. Do not disturb soil for 5 days after application.
	permethrin	Pounce 384 EC	180–390 mL	73–158 mL		Brussels sprouts, cabbage, cauliflower, broccoli. Use high rate on dry soils or large larvae. Apply up to 5-leaf stage. 12hr re-entry interval. Do not disturb ground for 5 days following application.
Perm-UP						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1 L	32	Cabbage, cauliflower, broccoli, Brussels sprouts, Chinese cabbage only. Apply at 2–5-leaf stage. 24-hr re-entry interval. (10 days for cauliflower.)
		Pyrinex 480 EC				
SLUGS						
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Use high rates on heavy infestations or after heavy rains.
carbamate (group 1A)	methomyl	Lannate TNG	775 g	314 g	30	Brussels sprouts only.
TWO-SPOTTED SPIDER MITES						
tetronic and tetramic acid derivatives (group 23)	spiromesifen	Oberon	500–600 mL	202–243 mL	7	Maximum 3 applications/yr. Apply before mite populations begin to build up. Control may not be apparent for 2–3 weeks, especially under cooler temperatures. 12-hr re-entry interval. If harvesting or pruning, 48-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).² Do not use on muck soils.

Table 9-16. Brassica Crop Cabbage Maggot Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate	PHI ¹	Notes
Planting-Water Treatment					
organophosphate (group 1B)	chlorpyrifos	Lorsban 50 W	32.5 g/100 L of water Apply 200 mL/plant.	32	Cabbage only. Do not use with starter fertilizers. 24-hr re-entry interval.
Treatment After Planting					
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E ²	210 mL/ 130 L of water/ 1,000 m of row	32	Cabbage, cauliflower, broccoli, Brussels sprouts, Chinese cabbage only. Maximum 2 applications/yr (3 on Brussels sprouts). 24-hr re-entry interval. 10 days for cauliflower.
				15	Pak-choy. 24-hr re-entry interval.
	Pyrinex 480 EC ²	150 mL/ 1,000 m of row		21	Chinese broccoli. Apply 5-7 days after seeding. 24-hr re-entry interval.
				21	Chinese broccoli. Apply 5-7 days after seeding. 24-hr re-entry interval.
				32	Direct-seeded cabbage, cauliflower, broccoli, Brussels sprouts only. 24-hr re-entry interval. 10 days for cauliflower.
	Lorsban 15 G	0.6-1.0 kg/ 1,000 m of row			
	Pyrifos 15 G				

¹ PHI = Pre-Harvest Interval (days).² Apply in a 10-cm (4-in.) band on each side of the plant 3 days after transplanting or 7-10 days after direct seeding.**Caution**

- Do not use emulsifiable formulations in the planting water.
- Do not add fertilizer to planting water containing an insecticide unless recommended by the manufacturer or until experience has proven the mixture to be safe.

CABBAGE MAGGOT

Identification: The cabbage maggot adult is a grey fly, approximately half the size of the common housefly. The female lays eggs in the soil at the base of seedlings. The small (1 mm) white eggs look like tiny grains of rice. The larvae are small (7 mm), legless and white. The maggots tunnel and feed along the roots of brassica crops. These wounds act as points of entry for soft rot bacteria.

Period of Activity: There are three periods of egg-laying throughout the season. The first generation is the most active and most damaging. It occurs from mid-May through June (flowering of yellow rocket). A second occurs in mid-July (flowering of day lilies) and a third in late August (flowering of goldenrod). These dates are approximate. Pest activity varies depending on regional temperatures and differences in soil type.

Thresholds: Cabbage root maggot management is primarily preventative. A Growing Degree Day (GDD) model developed for cabbage maggot uses a base of 6°C. First generation adults emerge between 314 and 398 GDD. Second generation adults emerge between 847 and 960 GDD. Third generation adults emerge between 1,446 and 1,604 GDD. See *Growing Degree Days*, on page 32.

Management Notes: See Table 9-16, *Brassica Crop Cabbage Maggot Control Recommendations*, this page. Later plantings are less likely to require protection.

FLEA BEETLES

Identification: Flea beetles are small (2-3 mm long), shiny black beetles. Adults are active and jump when disturbed. Feeding damage consists of numerous "shot-holes," 1-5 mm in diameter. At the seedling stage, flea beetle feeding can kill the plant.

Period of Activity: Adult flea beetles overwinter in leaf litter. They emerge and begin feeding on young plants in mid-May. Adults lay eggs near the roots of host plants throughout the spring and early summer. Larvae develop on the roots. In late July, adults emerge from the soil, feed and then seek hibernation sites in the fall.

Thresholds: Up to the 6-leaf stage, plants can tolerate no more than 1 flea beetle per plant. After this stage, feeding will not interfere with plant growth. Feeding damage at later stages may impact marketability and crop quality.

Management Notes: Early plantings may be protected with row covers. Transplants are less susceptible to damage than direct-seeded crops. Beetles tend to prefer specialty crops (e.g., Chinese cabbage, bok choy, daikon) over traditional brassica crops. Trap crops, such as Indian mustard, have worked well in traditional brassicas.

See Table 9-17, *Brassica Crop Flea Beetles and Thrips Control Recommendations*, opposite page. If black rot is present in the field, flea beetle management is important, as the beetle can spread black rot disease as it feeds.

Table 9-17. Brassica Crop Flea Beetles and Thrips Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes	
FLEA BEETLES							
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	42 mL	17 mL	1	Cabbage. Maximum 3 applications/yr. 24-hr re-entry interval.	
		Silencer 120 EC			3	Broccoli, cauliflower, Brussels sprouts. Maximum 3 applications/yr. 24-hr re-entry interval.	
	cypermethrin ²	Ripcord 400 EC ²	87.5–125 mL	35–51 mL	3	Cabbage, cauliflower, broccoli and Brussels sprouts. Maximum 3 applications/yr. Do not graze or feed treated foliage to livestock.	
	deltamethrin	Decis 5 EC	150–200 mL	61–81 mL	3	Use on cabbage only.	
	permethrin	Pounce 384 EC	90–180 mL	36–73 mL	2	Horseradish.	
					3	Cabbage, cauliflower, Brussels sprouts.	
					7	Broccoli.	
		Perm-UP	180 mL	73 mL	2	Horseradish. 12-hr re-entry interval.	
					3	Cabbage, cauliflower, Brussels sprouts. 12-hr re-entry interval.	
		90–180 mL	36–73 mL	7	Broccoli. 12-hr re-entry interval.		
Ambush 500 EC				140 mL	57 mL	2	Horseradish.
				70–140 mL	28–57 mL	3	Cabbage, cauliflower, Brussels sprouts.
7	Broccoli.						
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	1.5–2.0 L	0.6–0.8 L	7	Cabbage, cauliflower, broccoli and Brussels sprouts.	
		Thionex 50WP	1.1–1.75 kg	0.4–0.7 kg	7	Maximum 3 applications/yr.	
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	3	Cabbage and cauliflower.	
					5	Broccoli, kohlrabi and Brussels sprouts.	
					7	Horseradish.	
					21	Kale, Chinese cabbage and mustard greens.	
THRIPS							
pyrethroid (group 3)	cypermethrin ²	Ripcord 400 EC ²	87.5–125 mL	35–51 mL	3	Cabbage, cauliflower, broccoli, Brussels sprouts only. Maximum 3 applications/yr. Do not graze or feed treated foliage to livestock.	
		UP-Cyde 2.5 EC	200 mL	81 mL	3	Cabbage, cauliflower, broccoli, Brussels sprouts. Use with Agral 90 (0.03% v/v). Do not apply to muck soils. 12-hr re-entry.	

¹ PHI = Pre-Harvest Interval (days).² Do not use on muck soils.**THRIPS**

Identification: Thrips are small (<3-mm long), soft-bodied insects. They are cream-to-light-brown in colour. Thrips have sucking-rasping mouth parts and cause tissue damage when they feed on the leaves. The plant responds by forming scar tissue at the feeding site, giving the leaf a rough, rusty, warty appearance. Thrips feed on all brassica crops, however cabbage appears to be the most susceptible.

Period of Activity: Thrips overwinter on grasses (especially winter wheat) and alfalfa. They migrate into brassica crop fields as the weedy roadsides dry down and the winter wheat and alfalfa are harvested.

Thresholds: None have been established. If field monitoring indicates a need, start spraying for thrips once cabbage reaches the cupping stage.

Management Notes: Cabbage varieties vary in their susceptibility to thrips. Late plantings often suffer less damage than earlier ones. Harvest cabbage at the proper maturity. Over-mature cabbage is a prime target for thrips. Control of thrips during head development is very challenging.

See Table 9-17, *Brassica Crop Flea Beetles and Thrips Control Recommendations*, this page.

Table 9-18. Brassica Crop Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
biologicals (group 11)	<i>Bacillus thuringiensis</i>	Dipel 2X DF	55-550 g	22-220 g	0	See the label for a complete list of all brassica crops, including specialty brassicas. Use 275-550 g/ha (110-220 g/acre) for loopers.
			275-550 g	111-220 g	0	Mustard greens only.
		Thuricide HPC	2.0-4.25 L	0.8-1.7 L	0	See the label for a complete list of all brassica crops, including specialty brassicas. Use higher rates for looper control, heavy infestations or when foliage is dense.
		Bioprotec CAF	1.4-2.8 L	0.56-1.1 L	0	
spinosyn (group 5)	spinosad	Success 480 SC	182 mL	74 mL	3	See the label for a complete list of all brassica crops, including specialty brassicas. Maximum 3 applications/yr. Maintain a spray pH of 6 or higher. 3-day re-entry interval for tying and harvest activities.
		Entrust 80 W	109 g	44 g	3	
	spinetoram	Delegate WG	140-200 g	57-81 g	1	Use the higher rate for high infestations or advanced growth stages of the target pest. Maximum 3 applications/yr. 12-hr re-entry.
diamides (group 28)	chlorantraniliprole	Coragen	250 mL	101 mL	3	Maximum of 4 applications/yr.
pyrethroid ² (group 3)	deltamethrin	Decis 5 EC	150-200 mL	61-81 mL	1	Brussels sprouts only.
					3	Cabbage, cauliflower, broccoli only.
					5	Kale only.
	lambda-cyhalothrin	Matador 120 EC Silencer 120 EC	42 mL	17 mL	1	Cabbage. Imported cabbageworm and diamondback moth larvae. 24-hr re-entry interval.
					3	Broccoli, cauliflower, Brussels sprouts. Imported cabbageworm and diamondback moth larvae. 24-hr re-entry interval.
			83 mL	34 mL	1	Cabbage. Cabbage looper. 24-hr re-entry interval.
					3	Broccoli, cauliflower, Brussels sprouts. Cabbage looper. 24-hr re-entry interval.
	cypermethrin	Ripcord 400 EC	87.5-125 mL	35-51 mL	3	Cabbage, cauliflower, broccoli, Brussels sprouts only. Do not apply to muck soils. Do not graze or feed treated foliage to livestock.
		UP-Cyde 2.5 EC	140 mL	57 mL	3	Cabbage, cauliflower, broccoli, Brussels sprouts only. Add Agral 90 at (0.03% v/v). Do not apply to muck soils. Maximum of 3 applications/yr at 2 week intervals.
	permethrin	Pounce 384 EC	90-180 mL	36-73 mL	3	Cabbage, cauliflower, Brussels sprouts, pak choy and Chinese cabbage.
					7	Broccoli, Chinese broccoli.
					3	Pak choy and Chinese cabbage.
		Perm-UP	90-180 mL	36-73 mL	3	Cabbage, cauliflower, Brussels sprouts, pak choy and Chinese cabbage. Add Agral 90 (0.3% v/v) to improve wetting and coverage. 12-hr re-entry interval.
					7	Broccoli and Chinese broccoli. Add Agral 90 (0.3% v/v) to improve wetting and coverage. 12-hr re-entry interval.
		Ambush 500 EC	140 mL	57 mL	3	Cabbage, cauliflower, Brussels sprouts, pak choy, Chinese cabbage.
					7	Broccoli.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1-1.75 kg	0.4-0.71 kg	7	Cabbage, cauliflower, broccoli and Brussels sprouts.
		Thiodan 4 EC	1.5-2.0 L	0.6-0.8 L	7	Use high rate on loopers.

¹ PHI = Pre-Harvest Interval (days).² The carbamates and the pyrethroids have provided inconsistent control in some areas.

Table 9-18. Brassica Crop Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
carbamate ² (group 1A)	methomyl ²	Lannate TNG ²	270-540 g	109-218 g	1	Cabbage. 24-hr re-entry interval.
					7	Cauliflower, broccoli, Brussels sprouts. 24-hr re-entry interval.
	carbaryl	Sevin XLR	2.5-5.25 L	1-2.1 L	3	Cabbage and cauliflower.
					5	Broccoli, Brussels sprouts and kohlrabi.
					7	Horseradish.
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75-1.1 kg	0.3-0.4 kg	21	Kale, Chinese cabbage and mustard greens.
					28	Cabbage, Brussels sprouts, cauliflower only. Maximum 4 applications/yr. 12-hr re-entry interval.
	naled	Dibrom	1.1-2.2 L	0.4-0.9 L	4	Broccoli, Brussels sprouts, cabbage, cauliflower, kale and mustard greens. High rate for loopers only. 48-hr re-entry interval.
					21	For cabbage, cauliflower. 48-hr re-entry interval.
	methamidophos	Monitor 480	1.1-2.25 L	0.4-0.9 L	14	Broccoli, Brussels sprouts. Use high rate on cabbage loopers. 48-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).² The carbamates and the pyrethroids have provided inconsistent control in some areas.**IMPORTED CABBAGEWORM, CABBAGE LOOPER, DIAMONDBACK MOTH CATERPILLAR****Identification:** Imported cabbageworm (ICW)

caterpillars are leafy green and velvety in appearance, with a pale yellow stripe down the centre of the back. The cabbage looper (CL) caterpillar is similar in size, smooth and pale green, with a thin white line along each side and two faint lines down the middle of the back. The cabbage looper moves like an "inchworm." Both the ICW and the CL chew large ragged holes in the leaves.

Diamondback moth (DBM) larvae are much smaller than both ICW and CL. When disturbed, they wiggle frantically, attach a silken thread to the leaf and dangle over the edge. Diamondback moth larvae chew through the inner-leaf layers, leaving the waxy epidermis, creating a "window-pane."

Period of Activity: Infestations of the ICW and DBM begin very early in the season. Cabbage looper do not usually appear until mid-July. However, they have been found earlier in the Southwestern Ontario municipalities of Chatham-Kent and Essex.

Thresholds: Using the Cabbage Looper Equivalent (CLE) method, thresholds are 0.3 for cabbage and 0.2-0.3 for cauliflower and broccoli.

Using the Percentage Infestation Method, thresholds are:

Cabbage	before head fill	20%-30%
	after	10%-15%
Cauliflower & broccoli	before head fill	20%-30%
	after	5%-10%

For more information on the calculation of these thresholds, see OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario*.

Management Notes: Insecticides are most effective against small larvae. Begin application of insecticides when young larvae are found and continue on a 5-10-day schedule, or as necessary for adequate protection of the crop. Scouting is an excellent way to assess the population of brassica crop caterpillars.

See Table 9-18, *Brassica Crop Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar Control Recommendations*, opposite page. Diamondback moth develops resistance very quickly. To limit the development of resistance, alternate between chemical groups. Use pyrethroid insecticides during the fall, as they are more effective under cool conditions.

SWEDE MIDGE

Identification: Swede midge feeds on all brassica crops. Clusters of eggs are laid on the youngest plant tissue. The translucent-to-creamy-yellow-white larvae are 3 mm in length when mature. When disturbed, larvae jump off plants.

Damaged seedlings often appear twisted and may have a noticeable brown scar or a gall at the growing point. Also look for brown, corky scarring along the leaf petiole. If damage occurs before the plant reaches the button stage, the plant will be barren or blind. Later feeding injury results in twisted and distorted heads.

Table 9–19. Brassica Crop Swede Midge and Pea Leafminer Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
SWEDE MIDGE						
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC Silencer 120 EC	83 mL	34 mL	1	Cabbage. Maximum 3 applications/yr. 24-hr re-entry interval.
					3	Broccoli, Brussels sprouts, cauliflower. Maximum 3 applications/yr. 24-hr re-entry interval.
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	35 g	7	See the label for a complete list of all brassica crops, including specialty brassicas. Maximum 5 applications/yr. Alternate sprays with other insecticide families. 12-hr re-entry interval.
PEA LEAFMINER						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	35 g	7	See the label for a complete list of all brassica crops, including specialty brassicas. Maximum 5 applications/yr. Alternate sprays with other insecticide families. 12-hr re-entry interval.
chitin synthesis inhibitor (group 17)	cyromazine	Citation 75 WP	188 g in 200 L water	76 g in 20 gal water	7	Leafy brassica greens only. Maximum 5 applications/yr. 12-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).

Period of Activity: First-generation swede midge adults emerge from overwintering from mid-May to the beginning of June. There are four to five overlapping generations of swede midge in Ontario.

Thresholds: Use a Jackson pheromone trap to monitor swede midge populations throughout the growing season. Apply insecticides as soon as possible once the threshold is reached.

Cabbage:	5–10 males/trap/day
Broccoli (in regions of low swede midge populations):	1 male/trap/day

For broccoli in areas with high swede midge populations, a threshold of 1–5 males/trap/day may be effective but has not been proven to be more effective than weekly calendar sprays.

Management Notes: The swede midge is very difficult to manage. Chop and bury infested residue. Most pupae are found within the top 5 cm of the soil and may remain dormant for 2 years. A 2–3-year rotation away from brassica crops is essential. Deep plowing is not an effective management option.

Foliar insecticides targeting adult swede midge are used with some success. Systemic insecticides are required to kill the larvae. See Table 9–19, *Brassica Crop Swede Midge and Pea Leafminer Control Recommendations*, this page.

For more brassica crop insect information, consult these OMAFRA Factsheets:

- *Caterpillar Pests of Cruciferous Crops*, Order No. 99-035
- *Tarnished Plant Bug Damage on Vegetable Crops in Ontario*, Order No. 98-025
- *Thrips on Onions and Cabbage*, Order No. 99-027
- *The Swede Midge — A Pest of Crucifer Crops*, Order No. 08-007

Nematode Control

See *Nematodes*, on page 63, for nematode control recommendations.

Physiological Disorders

CABBAGE SPLITTING

Well-developed cabbage heads may split or burst if rain or a heavy irrigation follows a dry spell. Splitting results from rapid new growth due to increased moisture. Maintain steady plant growth with timely irrigation.

BOLTING

Low temperatures early in the growing season may cause premature seedstalk development (bolting). Extreme changes in temperature, poor soil conditions or low nutrient levels also induce bolting. Some cultivars are more susceptible to bolting.

TIPBURN OF CAULIFLOWER, CABBAGE AND BRUSSELS SPROUTS

Tipburn can occasionally cause severe economic losses in cabbage, cauliflower and Brussels sprouts. Tipburn is a breakdown of plant tissue near the centre of the head in cabbage and Brussels sprouts, and on the inner wrapper leaves of cauliflower. It is a physiological disorder associated with an inadequate supply of calcium to leaf margins, causing a collapse of the tissue and death of the cells.

High temperatures and fluctuating soil moisture conditions hinder the movement of calcium into the leaves, leading to tipburn. Foliar applications of calcium will not necessarily prevent the occurrence of tipburn. Maintain steady plant growth with timely irrigation.

Secondary rot organisms such as *Erwinia* spp. can follow tipburn. Many varieties of cabbage and cauliflower have been noted to be resistant to tipburn. See *Calcium*, on page 15, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

CAULIFLOWER BUTTONING

Buttoning is the premature formation of a cauliflower curd. Buttoning usually occurs shortly after planting in the field. The curd forms very early in the plant's life, and the leaves are not large enough to nourish the curd to a marketable size.

Losses are usually most severe in early plantings during cold, wet seasons. Conditions that reduce the vigour of the plant and retard vegetative growth appear to encourage buttoning. Some cultivars are more susceptible than others. Conditions that may cause buttoning include:

- too-rapid hardening-off treatment of young plants raised under protection
- insufficient hardening-off treatment of young plants before being planted in the field
- unbalanced soil fertility in the field (particularly low nitrogen)
- low soil moisture
- cold weather, 4°C–10°C for 10 days or more, especially in combination with excess moisture
- certain diseases, insects and trace-element deficiencies, such as clubroot, root maggot and molybdenum deficiency (whiptail)

BROWN HEART OR HOLLOW STEM

Hollow stem in broccoli is often caused by boron deficiency; however, it may also be caused by fluctuations in growth due to heat or moisture stress. See *Boron*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Harvest Broccoli

Cut heads when the clusters are green and compact. Open, yellow clusters are undesirable. Terminal broccoli heads are cut with 15–20 cm of stem. Lateral shoots from the axils of the leaves develop into marketable heads soon after the terminal head is removed. These laterals produce a continuous crop for several weeks. Some of the new hybrids produce very few laterals. Continuity of production with these cultivars may be obtained by successive plantings in the spring and summer.

Brussels Sprouts

Begin harvest when the sprouts are firm and well formed. When hand-picking, break off the leaf below the sprout and remove the sprout. The upper sprouts continue to form and enlarge as the lower ones are harvested. Pick early sprouts as soon as they mature. Otherwise, they will open up, become soft, turn yellow and rot.

For once-over harvest, topping the plants will prevent any further extension of growth and encourage the maturity of the small sprouts at the top of the stem. Topping is normally done when the sprouts at the bottom of the stem are about 12–20 mm in diameter. A full stem of uniform, marketable-sized sprouts will develop about 4 weeks later. Do not de-leaf plants more than 1 day before harvest.

Cabbage

Harvest cabbage before the outer leaves begin to lose their colour. For best storage results, pick cabbage at a slightly immature stage. Immature heads will retain their colour for a longer period of time.

Cauliflower

A perfect head of cauliflower is essentially pure white or pale cream. Heads exposed to sunlight develop an objectionable yellow pigment. "Blanch" cauliflower by tying the outer leaves over the heads when the heads are 8–10 cm in diameter.

In hot weather, blanching may take only 3–4 days. In cool weather, when growth is slow, 8–12 days or more may be required. Mark heads tied at different times with different colours of twine or rubber bands to indicate probable maturity date. The inner wrapper leaves of some cultivars provide natural curd protection without tying.

Storage

Prevent the development of rots and disease in storage by removing field heat from the crop as soon as possible. Store all brassica crops at 0°C and 95%–100% relative humidity. See Table 6-3, *Storage Life for Fresh Vegetables in Commercial Storage*, on page 48.

CARROTS

Production Requirements

Carrots are a cool-season vegetable. They grow best in deep, well-drained muck and sandy loam soils. The desired pH is 5.5 in muck soils and 6.5 in sandy loam soils. Carrots are extremely sensitive to environmental conditions such as heat, soil compaction, drought stress and saturation. Continuous high temperatures in the latter stages of plant development may reduce yield, retard growth and produce a strong-flavoured, coarse root. Temperatures below 16°C also slow plant growth.

Carrots are planted mid-April to late-June. Most carrot varieties mature in 120–180 days. Fresh-market carrots are harvested from late July through October. Processing carrots are harvested October through November.

Recommended rotational crops: onions, beets, spinach, cereal crops

Do not rotate with: brassica crops, other umbellifera crops (e.g., celery, parsley)

Average Yields

Crop	per acre	per hectare
Processing	35–40 tons	78–90 tonnes
Fresh market	15–20 tons	34–45 tonnes

Cultivars

Growers and processors are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

The minimum soil temperature for seed germination is 4°C. Sow as early as soil and weather conditions permit in the spring, up to July 1. Late carrots may “burn off” if they emerge during hot, dry weather. Seed into moisture, 1.2–2 cm deep.

Carrot quality may be improved by using raised beds, 15–20 cm high. Beds that are 85 cm wide at the bottom and 50 cm wide at the top have yielded good results. Seed carrots in 3 or 4 rows on the centre of the bed at a rate to achieve 26 carrots/m for processing carrots and 120–140 carrots/m for fresh-market carrots.

Seeding Rates

	Metric	Imperial
Fresh market:	2–4.5 kg/ha	0.8–1.8 lb/acre
Processing:	1–2 kg/ha	0.4–0.8 lb/acre

Table 9–20. Carrot Nitrogen Recommendations (mineral soils)

Soil	Actual N kg/ha
Mineral Soils	
Preplant	70
Side-dress	40
Total	110

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10, and Table 9–20, *Carrot Nitrogen Recommendations (mineral soils)*, this page.

Broadcast and incorporate the recommended preplant nitrogen with all the required phosphate and potash. On mineral soils, apply side-dress nitrogen when the plants are 10 cm tall.

Ontario research has shown that carrots grown on established muck soils receive adequate nitrogen from the soil, and there is no yield response to added nitrogen.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, carrots grown on both mineral and muck soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, carrots grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Table 9-21. Carrot Seed Treatments

Trade Name	Active Ingredient	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL/ 100 kg seed	damping-off	For use in commercial seed-treatment plants only. Export use only.
Thiram 75 WP	thiram	90 g/ 25 kg seed	damping-off	Seed box treatment.
Rovral	iprodione	521 mL/ 100 kg seed	seed borne alternaria	For imported seed only.

Magnesium

Magnesium deficiency may occur on carrots. The usual symptoms are yellowing of older leaves while the veins remain dark green. See *Magnesium* and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Boron

Boron deficiency in carrots can cause the growing point to die off or cause internal breakdown of the roots. Boron is recommended on newly cultivated muck soils. Use caution when applying boron. This nutrient can build to toxic levels quite quickly, harming rotational crops.

Various sources of boron are available. See *Boron*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Copper

Copper (Cu) deficiency may occur on acid peat and muck soils resulting in carrot roots with poor orange colour. Apply 14–29 kg Cu/ha on newly cultivated muck soils. Subsequent applications may be made every 2 or 3 years at about one-third the rate recommended for new muck. See *Copper*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*, provides a comprehensive guide to IPM for carrots.

Diseases

DAMPING-OFF AND ROOT ROT

For identification and management information on these common vegetable diseases, see Chapter 8, *General Pest of Vegetable Crops*, on page 59. Also see Table 9-21, *Carrot Seed Treatments*, this page.

LEAF BLIGHTS

Identification: Two different fungi (*Alternaria dauci* and *Cercospora carotae*) and one type of bacteria (*Xanthomonas campestris*) cause leaf blights in carrots. *Alternaria* produces irregular brown spots (often surrounded by yellowish halos), mainly along the edges of carrot leaves. *Cercospora* causes circular grey or brown lesions on both leaves and petioles. Dark brown lesions with an irregular yellow halo characterize *Xanthomonas* infections.

Development: Both *Alternaria* and *Cercospora* fungi overwinter in crop residue of infected carrots. Their spores are dispersed by wind. All three diseases are favoured by warm, humid conditions in the 20°C–30°C range. Symptoms usually appear 10 days after infection.

Thresholds: Apply protectant fungicides when blight is first detected (on 1%–2% of the leaf area.)

Management Notes: After the initial fungicide application, apply a recommended fungicide at 7–10-day intervals. Extend the intervals between sprays when the weather is unfavourable for blight. After the leaves have closed over the rows, spray at 7–10-day intervals.

See Table 9-22, *Carrot Disease Control Recommendations*, next page.

Table 9-22. Carrot Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
LEAF BLIGHT						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.4-3.2 L	1.0-1.3 L	1	48-hr re-entry interval.
dithiocarbamate (group M3)	mancozeb	Manzate ProStick	2.25 kg	0.9 kg	7	Do not feed treated tops to livestock. 24-hr re-entry interval.
		Dithane DG				
		Penncozeb 80 WP				
	zineb	Zineb 80 W	1.1-3.3 kg	0.4-1.3 kg	7	
carboxamide + QoI (group 7 + 11)	boscalid + pyraclostrobin	Pristine WG	580-735 g	234-297 kg	0	Maximum 6 applications/yr. Do not make sequential applications. Use high rate under heavy disease pressure. 3-day re-entry interval for thinning or hand harvest.
QoI (group 11)	pyraclostrobin	Cabrio EG	0.56-1.1 kg	0.22-0.4 kg	3	Alternaria leaf blight. Maximum 2 sequential applications. Maximum 3 applications. 72-hr re-entry interval (hand-thinning).
			0.56-0.84 g	0.22-0.34 kg	3	Cercospora leaf blight. Maximum 2 sequential applications. Maximum 3 applications. 72-hr re-entry interval (hand-thinning).
carboxamide (group 7)	boscalid	Lance WDG	315 g	127 g	0	Alternaria leaf blight. Maximum 2 sequential applications. Maximum 5 applications/yr. 4-hr re-entry interval.
phenylpyrroles + anilino-pyrimidines (group 12 + 9)	cyprodonil + fludioxonil	Switch 62.5 WG	775-975 g in a minimum of 200 L water	314-395 g in a minimum of 20 gal water	7	Alternaria leaf blight. Maximum 3 applications/yr. Maximum 2 sequential applications. Use high rate under high disease pressure. 12-hr re-entry.
CAVITY SPOT						
phenylamides (group 4)	metalaxyl	Ridomil Gold 1G	25 kg	10 kg		215 g/100 m of raised bed. Apply product evenly with seed in the furrow.
QoI (group 21)	cyazofamid	Ranman 400 SC	0.44 L	0.18 L	30	Post-plant, pre-emergent application. Apply to soil 3 days after planting.
CROWN ROT/VIOLET ROOT ROT						
QoI (group 11)	azoxystrobin	Quadris Flowable	4-6 mL/100 m of row	1.2-1.8 mL/100 ft of row	40	Apply in-furrow at seeding or in one banded application over the row after emergence.
SCLEROTINIA WHITE ROT						
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	8-15 L	3-6 L		Suppression only. Begin application soon after emergence.

¹ PHI = Pre-Harvest Interval (days).**PYTHIUM****(ROOT DIEBACK, RUSTY ROOT, CAVITY SPOT)**

Identification: A variety of symptoms may result from *Pythium* infections, including leaf wilting and discolouration, deformed roots (short, stuffy, forked), rusty red roots and the formation of fibrous roots. Dark, oval lesions on the surface of the carrot root characterize cavity spot.

Development: *Pythium* is a persistent, soil-borne fungus that is often found in wet soils. Cavity spot lesions

usually start to appear in August and September and slowly enlarge while carrots are in storage.

Thresholds: None have been established.

Management Notes: Grow resistant cultivars, avoid problem fields and grow carrots on raised beds. See Table 9-22, *Carrot Disease Control Recommendations*, this page.

CROWN ROT, VIOLET ROOT ROT

Identification: Foliar symptoms of crown rot and violet root rot appear in patches across the field. Plants become stunted and yellow, followed by wilting and death of the foliage. Root symptoms do not show up until the carrot is mature. Crown rot produces large, grey-brown lesions near the top of the carrot root. Violet root rot covers the root with a thick, purplish fungal layer. When infected carrots are pulled, a considerable amount of soil adheres to them.

Development: Appears mid-summer.

Management Notes: The only practical control is to avoid previously infected areas, rotate for several years with grains and practice strict sanitation procedures to avoid spreading infected soil between fields.

SCLEROTINIA WHITE ROT

Identification: Sclerotinia white rot is typically a disease of stored carrots. The disease starts in the field and may infect plants before harvest. Infection begins at the base of the leaf stalk, causing the petiole to turn brown and die. In storage, infected roots develop a growth of white, cottony fungi and small black sclerotia. The fungus can quickly spread through healthy carrots while in storage.

Development: Optimum temperatures for infection are 15°C–20°C. However, sclerotinia white rot can still spread in storage as long as the temperatures are above 0°C. Development of the disease in the field occurs under cool, wet conditions. Sclerotinia overwinters in crop residue as hard, black sclerotia, which can survive in the soil for many years.

Management Notes: Rotate with onions, beets, spinach or cereal crops for 2–3 years. Use wider row spacings to encourage good air movement. Initial infection of storage carrots is less likely to occur if the relative humidity is less than 92% and the field heat is removed as quickly as possible. To reduce levels of sclerotinia rot, vertically trim the overlapping carrot tops 100 days after seeding.

ASTER YELLOWS

The symptoms of aster yellows on carrots first appear as a reddening of several leaves. Crown growth becomes yellow and brittle, followed by hairy root development. The aster leafhopper vectors and transmits aster yellows. See *Aster Leafhopper*, this page.

For more information, see the following OMAFRA Factsheets:

- *Identification and Management of Carrot Root Diseases*, Order No. 98-001
- *Management of Carrot Leaf Diseases*, Order No. 00-045

Insects**CUTWORMS, MILLIPEDES, WIREWORMS**

For identification and management information on these common vegetable insects affecting carrots, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–23, *Carrot Insect Control Recommendations*, on page 98.

ASTER LEAFHOPPER

Identification: These small, greenish-grey insects with six spots arranged in pairs on top of its head, feed on a wide range of plants, especially grasses, grains and vegetables.

Period of Activity: As the winter grains mature in late May and early June, local first-generation leafhoppers disperse to vegetable crops. Migration of leafhoppers from the U.S. into Ontario may also take place. Migrations into Ontario are not consistent from year to year, because leafhopper movements are influenced by wind and weather patterns. Both local dispersal and long-distance migration influence the incidence and severity of the aster leafhopper.

Thresholds: The Aster Yellows Index (AYI) determines the need to treat a crop. To use the AYI, monitor aster leafhoppers with a sweep net. Multiply the number of aster leafhoppers captured in 100 sweeps by the percentage of leafhoppers carrying aster yellows in your area (4%–5% is the currently recommended percent infectivity in Ontario). Use this formula:

$$\begin{array}{ccccc} \text{Infectivity rate} & & & & \\ (4\%–5\%) & \times & \# \text{ of leafhoppers} & = & \text{AYI} \\ & & (\text{per 100 sweeps}) & & \end{array}$$

AYI thresholds in carrots vary depending on varietal tolerance. If a carrot variety has not been evaluated for aster yellows tolerance, use an AYI threshold of 70.

Carrot Tolerance	Aster Yellows Index
Resistant	100
Intermediate	70
Susceptible	50

Management Notes: Grow resistant cultivars and remove perennial weeds from fields that may act as reservoirs. See Table 9–23, *Carrot Insect Control Recommendations*, next page.

Table 9-23. Carrot Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ASTER LEAFHOPPER						
carbamate (group 1A)	carbaryl	Sevin XLR	1.25-2.5 L	0.5-1.0 L	1	Use low rate on young plants. Do not graze livestock on carrot tops for 48 hr after treatment.
inorganic	kaolin clay	Surround WP	12.5-25 kg in 500 L water	5-10 kg in 45 gal water	0	For early applications, use the higher rate per 250 L water.
CARROT WEEVIL						
organophosphate (group 1B)	phosmet	Imidan 50 WP	2.25 kg	0.9 kg	40	Maximum 2 applications/yr. 5-day re-entry interval.
CARROT RUST FLY						
pyrethroid (group 4)	cypermethrin	Ripcord 400 EC	175 mL in 550 L water	71 mL in 55 gal water	35	Maximum 3 applications/yr. Do not graze livestock on treated carrot tops.
		UP-Cyde 2.5 EC	280 mL in 550 L water	112 mL in 55 gal water	35	Maximum 3 applications/yr. 12-hr re-entry interval.
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.4 kg	10	
CUTWORMS²						
pyrethroid (group 4)	permethrin	Pounce 384 EC	180-390 mL	73-158 mL		Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application. Use high rate on large larvae, dry soils or muck soils. 12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC	140-300 mL	57-121 mL		
pyrethroid (group 4)	cypermethrin	Ripcord 400 EC	175 mL	71 mL	21	Do not disturb soil for 5 days after application. Do not graze livestock on treated carrot tops.
		Lorsban 4E	2.4-4.8 L	0.9-1.9 L	60	Use high rate on large larvae or dry soils. 24-hr re-entry interval.
		Pyrinex 480 EC	2.4-4.8 L in 200-400 L water	0.9-1.9 L in 18-26 gal water	60	2 applications/yr. Use high rate on large larvae or dry soils. 24-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).² Seedling treatments.**CARROT RUST FLY**

Identification: The adult rust fly is shiny and black, measuring approximately 6 mm in length. It has an orange head, brown eyes and pale, yellow legs. The larva is cream-white and legless with dark mouthhooks. Larvae feed on the root hairs for up to a month before tunnelling into the carrot, where they continue feeding. Feeding damage from rust fly larvae is usually limited to the lower two-thirds of the root.

Period of Activity: The carrot rust fly overwinters as a pupa in the soil and usually has two generations per year. The first generation often coincides with lilac bloom, the second begins in mid-August. Occasionally, sufficient heat units are accumulated so that a third generation emerges in late September or October. This third generation usually occurs too late in the season to have any serious effect on the crop.

Thresholds: Control adults if populations reach a level of 0.1 flies/trap/day (fresh market) or 0.2 flies/trap/day (processing). Rust flies are no longer a concern once the crop is within 21 days of harvest. A Growing Degree Day (GDD) model has been developed for carrot rust flies. Using a base of 3°C, first-generation adults emerge between 329 and 395 GDD. Second generation adults emerge between 1,399 and 1,711 GDD. For more information, see *Growing Degree Days*, on page 32.

Management Notes: Crop rotation will reduce background populations of the carrot rust fly. Consider late seeding to avoid first-generation damage. Avoid growing carrots in sheltered areas where rust flies are more prevalent.

See Table 9-23, *Carrot Insect Control Recommendations*, this page.

CARROT WEEVIL

Identification: The carrot weevil adult is a dark-brown snout beetle (6 mm long). It overwinters in the plant debris of previously infested fields. Feeding damage commonly occurs in the upper third of the root. Developing larvae tunnel into young, slender roots, causing the plants to wilt and die.

Period of Activity: Adult females are not attracted to carrots prior to the first true leaf stage. Egg-laying occurs from mid-May to early June. Eggs hatch in 1–2 weeks, and larvae feed on the roots for at least 3 weeks after emergence. Adults will emerge 2 weeks later. A second generation may occur on early carrot crops under warm weather conditions.

Thresholds: A Growing Degree Day (GDD) model for egg-laying has been developed. Using a base of 7°C, first egg-laying is expected at 147 GDD, which occurs from mid-May to early June. Expect 90% egg-laying at 455 GDD. For more information on GDD models, see *Growing Degree Days*, on page 32.

Management Notes: Time treatments to target adults prior to egg-laying. Crop rotation and weed control around field edges may reduce overwintering populations. The egg parasite *Trichobius sordidatus* (a small braconid wasp) provides some biological control. See Table 9–23, *Carrot Insect Control Recommendations*, opposite page.

Nematode Control

For nematode control recommendations, see *Nematodes*, on page 63.

Storage

Store mature topped carrots for up to 4–5 months at 0°C and a relative humidity of 90%–98%. Rapid cooling of carrots after harvest is very important for reducing storage rots.

Proper sanitation of the storage and handling equipment will help reduce storage losses. See *Storage Sanitation*, on page 50.

See the OMAFRA Factsheet, *Long-Term Storage of Carrots*, Order No. 98-073.

For more information, see the following OMAFRA Factsheets and publication:

- *Carrot Insects*, Order No. 93-077
- *The Aster Leafhopper and Aster Yellows*, Order No. 98-057
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

CELERY

Production Requirements

Celery is a cool-season vegetable. Muck soils with high water-holding capacity and a pH of 5.5 are ideal for production. Irrigated celery may also be grown successfully on well-drained mineral soils with a target pH of 6.0. Celery can withstand light frosts, but the crop may be damaged if temperatures remain below 0°C for a prolonged period of time. Premature seed stalk development or "bolting" may occur if young plants are exposed to temperatures below 13°C for 10 days or more.

Most celery varieties are ready for harvest 80–90 days after transplanting. Celery harvest begins in late July and continues until several frosts have occurred.

Recommended rotational crops: carrots, onions, potato, radishes, lettuce

Do not rotate with: celeriac, celery root, other umbellifera crops (e.g., carrots, parsley)

Average Yields

Crop	per acre	per hectare
Processing	20–30 tons	45–68 tonnes
Fresh market	750–1,000 60-lb cartons	2,200 27-kg cartons

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Spacing and Seeding

Early celery is started from seed in the greenhouse at the beginning of February. The minimum soil temperature required for seed germination is 4°C. See *Transplanting*, on page 39. If row covers are used, transplanting can occur as early as April 1. Seeding continues through June 1 for July transplanting.

Plants for the late crop may be started in irrigated, outdoor seedbeds. Direct-seed outdoor transplant beds in rows 15–20 cm apart, at a rate of 80–110 seeds/m of row. Seed may also be broadcast onto a finely prepared bed at a rate of 15 g/10 m². However, the first method provides sturdier plants.

FIELD SPACING

	Metric	Imperial
Row width:	50–55 cm	20–22 in.
In-row spacing:	15 cm	6 in.
Rate:	approx. 140 g seed/ha	approx 56 g seed/acre

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application (see Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10).

Broadcast and incorporate recommended preplant nitrogen with all the required potash and potassium. See Table 9–24, *Celery Nitrogen Recommendations*, this page.

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, celery grown on both mineral and muck soils is unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, and Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, celery grown on both mineral and muck soils is unlikely to respond to additional potash applications.

Table 9–24. Celery Nitrogen Recommendations

Soil Type	Actual N kg/ha
Mineral Soils	
Preplant	135
Side-dress	30 ¹
Total	195
Muck Soils	
Preplant	80
Side-dress	40 ¹
Total	160

¹ Up to 2 applications.

For soils testing lower than 181 mg K per L (ppm), see Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1-12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Calcium

Calcium deficiency results in a physiological disorder known as "black heart." The celery heart turns black, while the outer leaves are unaffected. If celery is under heat and moisture stress, weekly foliar calcium sprays directed into the heart of the plant may reduce black heart symptoms. See *Calcium*, on page 15, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Magnesium

Magnesium deficiency appears as yellowing of the tips of older leaves, progressing around leaf margins and between veins. Some celery cultivars are inefficient at taking up magnesium from the soil. Where soil magnesium levels are low, apply foliar sprays starting when the plants are about one-third grown. See *Magnesium*, on page 16, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Boron

Boron deficiency results in a physiological disease known as "cracked stem" or "cat scratches." Use caution when applying boron. This nutrient builds to toxic levels quite quickly, harming rotational crops.

See Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*, provides a comprehensive guide to IPM for celery.

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases, see Chapter 8, *General Pests of Vegetable Crops*, on page 59. Buy hot-water-treated seed to avoid seed-borne blight fungi.

Fungicides registered for greenhouse transplant production are listed in Table 9-25, *Celery Seed Treatments and Transplant Disease Control Recommendations*, this page. For more information on vegetable transplant production, see Chapter 5, *Seeding and Transplanting*, on page 37.

EARLY BLIGHT, LATE BLIGHT AND BACTERIAL LEAF SPOT

Identification: The symptoms for all three diseases include small yellow specks or lesions on the leaves. Older lesions frequently turn tan-to-brown coloured. Early and late blight lesions may enlarge to 1 cm or more in diameter. Under heavy bacterial leaf spot pressure, lesions will merge and kill infected leaves.

Development: Early blight occurs during mid-summer when heavy evening dews follow sunny, warm, daytime weather. Late blight starts in the lower foliage and moves upwards. All three of these diseases overwinter in crop residue. Following the initial infection, splashing water and the wind disperse disease spores.

Table 9-25. Celery Seed Treatments and Transplant Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate
DAMPING-OFF, FUNGUS ROOT ROT			
Seed Treatments			
dithiocarbamate (group M3)	thiram	Thiram	90 g/ 25 kg of seed
phenylamides (group 4)	metalaxyl-M	Apron XL LS	20-40 mL/ 100 kg of seed
Greenhouse Treatments			
phthalimide (group M4)	captan	Maestro 80 DF ¹	1.25 kg/ 1,000 L of water Apply 50-85 L of solution per 100 m ² (1,076 ft ²)
dithiocarbamate (group M3)	oxine benzoate	No-Damp ²	10 mL/ L of water

¹ 48-hr re-entry interval.

² Soil treatment.

Table 9–26. Celery Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
CELERY BLIGHT						
chloronitrile (group M5)	chlorothalonil	Bravo 500	1.6–2.4 L	0.6–0.9 L	7	Early blight. Apply on a 3–5-day schedule. 48-hr re-entry interval.
			2.4–4.0 L	0.9–1.6 L	7	Late blight. Apply on an 8–10-day schedule. 48-hr re-entry interval.
dithiocarbamate (group M3)	mancozeb	Dithane DG	2.25 kg	0.9 kg	14	Wash and trim. 24-hr re-entry interval.
		Penncozeb 80 WP				
		Manzate Pro-Stick				
	metiram	Polyram DF	2.25–3.25 kg	0.9–1.3 kg	14	After transplanting only. Use higher rate during periods of rain or heavy dew.
inorganic (group M1)	zineb	Zineb 80 W	1.1–3.3 kg	0.4–1.3 kg	14	Use higher rates as crop grows.
	copper sulphate	Copper 53 W	3.25–6.5 kg	1.3–2.6 kg	1	
	copper oxychloride	Copper Spray	4.0 kg in 1,000 L water	1.6 kg in 90 gal water	1	
strobilurin/ anilid (group 7/11)	pyraclostrobin + boscalid	Prisine WG	1 kg	0.4 kg	0	Suppression of early and late blight. Maximum 2 applications/yr (late blight) or 1 application/yr (early blight). 24-hr re-entry interval for most activities. 9 days for hand-harvesting and thinning.
PINK ROT (SCLEROTINIA)						
biological	<i>Bacillus subtilis</i>	Serenade Max	3–6 kg	1.2–2.4 kg		Make the first application approximately 8 weeks before harvest and repeat in 14-day intervals. Apply in sufficient water to ensure thorough coverage to the base of the plants.

¹ PHI = Pre-Harvest Interval (days).

Thresholds: None have been established.

Management Notes: If the field has a history of blights, rotate out of celery for at least 2 years. Use hot-water-treated seed and select resistant varieties. Grow seedlings in a commercial soilless mix or heat-pasteurized soil. Rotate outdoor seedbeds. Do not transplant diseased seedlings into the field.

Begin a protectant fungicide program when the seedlings are about 5 cm high. Apply one or two applications before transplanting (see Table 9–25, *Celery Seed Treatments and Transplant Disease Control Recommendations*, previous page). After transplanting, begin fungicide applications when plants are one-third grown or when the first signs of disease are detected. See Table 9–26, *Celery Disease Control Recommendations*, this page.

FUSARIUM YELLOW

Identification: Infected plants are often greenish-yellow in colour and stunted. The fungus infects the root and basal plate. It causes a darkening of the vascular tissues, followed by basal rot and plant death.

Development: This fungus persists in soil for many years. Fusarium yellows may be introduced on infected transplants, on workers, equipment and soil carried by wind or water erosion.

Management Notes: Sanitation is important in preventing the spread of this disease. Avoid cultivation practices that spread infested soil from one area to another. Do not return infected celery trimmings to fields after harvest. Practice a 2- to 3-year rotation with onions or lettuce to reduce spore populations in infested fields. Avoid the use of carrots in the rotation.

Tolerant varieties will withstand moderate levels of the fungus. High fungal populations, excessive heat and drought stress may diminish this tolerance.

PINK ROT (SCLEROTINIA)

Identification: The *Sclerotinia* fungi cause damping-off of seedlings. Infected celery plants develop pink or reddish-brown water-soaked areas on petioles or stalks. Under severe conditions, secondary infections occur, causing plant collapse.

Table 9-27. Celery Aphid Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	23–35 g	7	Maximum 5 applications/yr. Alternate applications with other insecticide families. 12-hr re-entry interval.
tetrone and tetramic acid derivatives (group 23)	spirotetramat	Movento 240 SC	220–365 mL	89–148 mL	3	Most effective on young stages of pest development. Slow activity; control may not be apparent for 2–3 weeks. 12-hr re-entry interval.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.75 kg	0.7 kg	14	Trim the celery of all outer leaves.
		Thionex 50WP		0.8 L		
		Thiodan 4 EC	2.0 L	0.8 L		
organophosphate (group 1B)	naled	Dibrom	1.1–1.65 L in 100–300 L water	0.4–0.6 L in 9–27 gal water	4	48-hr re-entry interval.
	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	21	Green peach aphid only. Maximum 4 applications/yr. 24-hr re-entry. Workers in the fields must wear gloves for 2 weeks following application.

¹ PHI = Pre-Harvest Interval (days).

Development: Pink rot is an occasional problem during wet seasons.

Management Notes: Wider row spacings will facilitate airflow and reduce the chance of infection. If a field is infected with pink rot, rotate to onions or another non-susceptible crop. *Sclerotinia* also causes white mould in carrots. See Table 9-26, *Celery Disease Control Recommendations*, opposite page.

CUCUMBER MOSAIC VIRUS (CUMV)

Identification: Symptoms on celery include a mosaic pattern on the leaf and downward curling of the petioles. A greenish-yellow discoloration develops along the veins. Brown, irregularly shaped, sunken lesions also form on the petioles as the virus develops.

Development: This virus is spread by aphids and usually follows periods of high aphid activity.

Management Notes: Control weeds bordering the crop area. Remove infected plants if mosaic symptoms are noticed early in the season. See *Aphids*, on page 60, and *Viruses (General)*, on page 59.

ASTER YELLOWS

Identification: Symptoms on celery first appear as a bright yellowing of leaves. Excessive, brittle, yellow crown growth follows, accompanied by severe twisting and secondary bacterial infections. Removing infected plants is an effective way to reduce in-field sources of diseases. Aster yellows are transmitted by the aster leafhopper. See *Aster Leafhopper*, on page 97.

For more information, see these OMAFRA Factsheets and publication:

- *Identification and Management of Celery Leaf Blights*, Order No. 00-093
- *Fusarium Yellows of Celery*, Order No. 89-180
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

Insects

APHIDS, CUTWORMS, TARNISHED PLANT BUG

For identification and management information on these common vegetable insects affecting celery, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9-27, *Celery Aphid Control Recommendations*, this page.

ASTER LEAFHOPPERS

See the Aster Yellows Index (AYI) calculation in *Aster Leafhopper*, on page 97.

For celery, treat when the AYI equals 30–35.

See Table 9-28, *Celery Insect Control Recommendations*, next page.

LEAFMINERS

Identification: Pea leafminer (PLM) adults are small, black-to-grey flies with yellow markings. They lay their egg on the leaves, leaving small “bronzed” puncture marks. Females pierce the leaves to feed on plant sap. Larvae feed between the upper and lower surface of the leaves, creating relatively straight mines that follow the leaf veins. Other leafminers tend to make curved, serpentine mines.

Table 9–28. Celery Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ASTER LEAFHOPPER						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	86 mL	35 mL	7	Maximum 3 applications/yr.
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	5	
organophosphate (group 1B)	malathion	Malathion 500 E	2.25 L	0.9 L	7	
inorganic	kaolin clay	Surround WP	12.5–25 kg in 500 L water	5–10 kg in 45 gal water	0	For early applications, use the higher rate in 250 L (22 gal) water.
CARROT WEEVIL						
organophosphate (group 1B)	phosmet	Imidan 50 WP	2.25 kg	0.9 kg	40	Maximum 2 applications/yr. 5-day re-entry interval.
TARNISHED PLANT BUG						
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.75 kg	0.7 kg	14	Trim the celery of all outer leaves.
		Thionex 50WP				
		Thiodan 4 EC	2.0 L	0.8 L		
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	21	Maximum 4 applications/yr. 24-hr re-entry interval. Workers must wear gloves in the field for 2 weeks following application.
CABBAGE LOOPER						
biological (group 11)	<i>Bacillus thuringiensis</i>	Thuricide HPC	2.0–4.25 L	0.8–1.7 L	0	
spinosyn (group 5)	spinosad	Success 480 SC	182 mL	74 mL	1	Maximum 3 applications/yr.
		Entrust 80 W	109 g	44 g	1	
	spinetoram	Delegate WG	140–200 g	57–81 g	1	Maximum 3 applications/yr. 12-hr re-entry.
diamides (group 28)	chlorantraniliprole	Coragen	250 mL	100 mL	1	Maximum of 4 applications/yr.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.75 kg	0.7 kg	14	Trim the celery of all outer leaves.
		Thionex 50WP				
		Thiodan 4 EC	2.0 L	0.8 L		
organophosphate (group 1B)	naled	Dibrom	1.1–1.65 L in 100–300 L water	0.4–0.66 L in 9–27 gal water	4	48-hr re-entry interval.
CUTWORMS ²						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–0.5 L	70	24-hr re-entry interval. Use high rate on large larvae or dry soils.
		Pyrinex 480 EC				
LEAFMINERS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	35 g	7	Pea leafminer only. Maximum 5 applications/yr. Alternative applications with other insecticide families. 12-hr re-entry interval.
chitin biosynthesis inhibitor (group 17)	cyromazine	Citation 75WP	188 g	76 g	7	12-hr re-entry interval. Apply when leafminer larvae first appear. Maximum 5 applications/yr.
(group 6)	abamectin	Agri-mek 1.9% EC	0.6–1.1 L	240–445 mL	14	Use lower rate under low pest pressure. Maximum 4 applications/yr.

¹ PHI = Pre-Harvest Interval (days).² Seedling treatments.

Leafminer feeding reduces the plant's photosynthetic capacity. The mines also affect marketability and provide an entrance for disease organisms.

Period of Activity: Optimal temperatures for leafminer development range from 21°C–32°C. Egg-laying is reduced at temperatures below 10°C. The PLM is typically a late-season pest with populations peaking from the end of August through the middle of September.

Thresholds: None have been established.

Management Notes: Reduce severe damage by harvesting susceptible crops before the beginning of September when populations tend to rise. Apply insecticides as soon as PLM adults first appear. Chemical control options are listed in Table 9–28, *Celery Insect Control Recommendations*, opposite page.

CARROT WEEVIL

Carrot weevil can seriously damage celery roots and crowns, causing stunting and plant collapse. For monitoring information, see *Carrot Weevil*, on page 99. Chemical control options are listed in Table 9–28, *Celery Insect Control Recommendations*, opposite page.

CABBAGE LOOPER

Although this is a rare problem in Ontario celery, cabbage looper can cause sporadic damage. The suggested threshold is 5%. See Table 9–28, *Celery Insect Control Recommendations*, opposite page.

Nematode Control

For nematode control recommendations, see *Nematodes*, on page 63.

Storage

Do not store celery damaged by frost, insects, disease or handling. A relative humidity of 95%–98% and a temperature of 0°C are ideal for storage. Store celery in a room that is free from odours. Stalks readily absorb foreign flavours. Remove field heat by hydro-cooling or vacuum-cooling before placing in large storage rooms.

Caution

Some individuals may be sensitive to furocoumarins, the natural chemicals found in celery. These substances increase in diseased celery. Using rubber gloves when handling celery and leg protection when walking in the field will prevent the development of skin rashes.

For more information on insect pest management in celery, see these OMAFRA Factsheets and publication:

- *The Aster Leafhopper and Aster Yellows*, Order No. 98-057
- *Caterpillar Pests of Crucifer Crops*, Order No. 99-035
- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053
- *Publication 700, IPM for Onions, Carrots, Celery and Lettuce in Ontario*

CUCURBITS

CUCUMBER, MUSKMELON, WATERMELON, PUMPKIN, SQUASH, GOURDS (ALSO KNOWN AS VINE CROPS)

Production Requirements

Cucurbits are warm-season vegetables. They do not tolerate frost. Temperatures below 10°C impact crop growth and negatively affect fruit quality. Cucurbits require well-drained, compaction-free locations with ample fertility. The optimum soil pH is 6.1 to 6.5.

Recommended rotational crops: corn, cereal crops, brassica crops

Do not rotate with: beans, peppers, cucurbits

Average Time From Flower Set to Harvest

Cucumber (pickling)	4–5 days
Cucumber (slicing)	15–18 days
Muskmelon	40 days
Pumpkin	60–70 days
Summer squash	3–8 days
Winter squash	60–70 days
Watermelon	40 days

Average Yields

Crop	per acre	per hectare
Cucumbers (processing – machine harvest)	4 tons	9 tonnes
Cucumbers (processing – hand harvest)	8–12 tons	18–27 tonnes
Cucumbers (slicing)	200–400 bu boxes	500–1,000 bu boxes
Fresh-market dills	160–400 bu boxes	400–1,000 bu boxes
Muskmelons	25 bins	60 bins
Pumpkins	50 bins	125 bins
Squash (winter)	15–20 bins	40–50 bins
Watermelon	15–25 ton	34–56 tonnes
Zucchini	700 ½-bushel boxes	1,600 ½-bushel boxes

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Processing cucumber hybrids have a predominately female (gynoeious) flowering habit. However, not all gynoeious hybrids produce 100% female flowers. Ontario day-lengths and temperatures may be responsible for the presence of male flowers on

these hybrids. All gynoeious hybrid seed contains 10%–15% standard (monoecious) cultivar, added as a pollinator. For satisfactory fruit set, 10%–20% of the plants should contain a large number of male flowers.

In other cucurbit crops, the normal ratio of male to female flowers is often 10:1. This ratio can occasionally reach 100:1 without a significant impact on yield.

Seeding and Spacing

Total cucurbit yields tend to increase with plant density. Processing cucumbers for machine harvest benefit the most from close spacings. In other cucurbits, high plant populations may result in harvest problems due to excessive vine growth. An overly dense canopy is also more conducive to disease pressure.

In pumpkins and squash, fruit size decreases as plant populations increase. Larger-sized pumpkin and winter squash varieties will benefit from wider spacing. Extremely wide rows are slow to close canopy, resulting in higher levels of weed pressure.

Plant seeds into moisture, no more than 2–2.5 cm deep. Deeply planted seed is often slow to emerge, resulting in lower plant populations. Quick, uniform emergence is essential to avoid uneven stands weakened by insects and disease. Delay planting until the soil temperature is 15°C or higher. The optimum soil temperature range at planting is 25°C–30°C.

Pickling cucumbers are usually field-seeded from late May to early June for the hand-pick crop. Seeding for mechanical harvesting can be done until mid-July, depending on the buyer's specifications.

Pumpkins and squash for the Hallowe'en market are usually seeded from late May to mid-June. Plant melon transplants after the risk of spring frost has passed (see Table 4–1, *Average Frost-Free Period in Climatic Zones of Ontario (1976–2005)*, on page 32).

See Table 9–29, *Cucurbit Crop Spacing*, opposite page.

For information on producing cucurbit crop transplants, see *Transplanting*, on page 39.

Table 9–29. Cucurbit Crop Spacing

Crop	Metric		Imperial	
	Row Spacing	In-Row Spacing	Row Spacing	In-Row Spacing
Cucumbers				
Fresh	1.2–1.8 m	30 cm	4–6 ft	12 in.
Cucumbers (processing)				
Hand-pick	1.1–1.2 m	10–15 cm	3.5–4 ft	4–6 in.
Machine harvest	50–75 cm	10 cm	20–30 in.	4 in.
Pumpkins & Squash¹				
Standard types	1.5–3 m	60–150 cm	5–10 ft	2–5 ft
Semi-bush types	1.2–1.5 m	45–90 cm	4–6 ft	1.5–3 ft
Small bush types	0.9–1.2 m	45–90 cm	3–6 ft	1.5–3 ft
Melons²				
Muskmelons	1.5–1.8 m	60–90 cm	5–6 ft	2–3 ft
Watermelons	1.8–2.5 m	90–120 cm	6–8 ft	3–4 ft

¹ Varieties with large fruit size (over 14 kg or 30 lb) benefit from wider rows and plant spacings. Gourds and mini-pumpkins respond to significantly higher plant populations (up to 14,800 plants/hectare).

² Approximately 2.2 kg of seed are required to produce enough melon seedlings for 1 ha.

Seedless Watermelon Production

Seedless (triploid) watermelons will not set fruit unless pollinated by a normal (diploid) watermelon variety. Use one pollinator plant for every 2 seedless ones. For the best results, mix the pollinator varieties in the same row as the triploids. Plant a pollinator with a different fruit type to distinguish it from the seedless variety at time of harvest. Under cool or stressful growing conditions, some seed development may occur in seedless watermelons.

Plasticulture

Cucurbit crops (especially musk and watermelons) respond well to plastic mulch, row covers and drip irrigation. However, keep in mind that all cucurbits are very sensitive to low temperatures. Row covers may not provide significant frost protection if the crop is planted too early. Monitor the temperature inside the row cover regularly. Ventilate when the temperature inside reaches 35°C or higher. Remove the cover once the risk of cold temperatures has passed. Covers must be removed prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. For more information, see *Season Extension*, on page 34.

Pollination

All the cucurbit crops depend on insects to transfer pollen from the male to the female blossoms. Each female blossom must be visited 15–20 times for adequate pollination to occur. Poorly pollinated fruit exhibit awkward shape and poor size.

Native pollinators are commonly found in many pumpkin and winter squash fields. They are less common in cucumbers, muskmelons and watermelons. Assess all cucurbit fields for bee activity at early bloom. If there is adequate pollination occurring, a clear buzz of activity can be heard in the field in the early morning hours. Consider introducing one colony of honeybees for every hectare. Aim to have the hives in the field at first bloom.

Insecticides will poison bees. Avoid spraying insecticides during bloom. If necessary, spray only in the evening or at night, after bees have finished foraging for the day. If possible, remove hives from the field prior to spraying. See *Prevent Bee Poisoning*, on page 53.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Apply up to 110 kg N/ha. Broadcast 65 kg N/ha and all the phosphate and potash required prior to planting. Side-dress the remainder of the nitrogen before the vines start to run. On sandy soils, a second application may be necessary after the vines begin to run.

Alternatively, up to 100 kg of N + K₂O/ha can be applied in a band, 5 cm to the side and 5 cm below the seed at planting. Broadcast the remainder of the fertilizer requirements before planting or side-dress before the vines start to run.

Over-application of nitrogen may result in excessive vine growth and reduced fruit yields.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, cucurbit fields are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Table 9–30. Cucurbit Nitrogen and Potash Injection Schedules

Stage	Rate per week
Transplanting to fruit set	5 kg/ha
Fruit sizing to harvest	10 kg/ha
During harvest	5 kg/ha

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, cucurbit fields are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Fertigation

For fertigated cucurbit crops, broadcast all the phosphate requirement and approximately 30%–50% of the nitrogen and potash requirements prior to planting. Inject the remainder through the drip irrigation system at the rates shown in Table 9–30, *Cucurbit Nitrogen and Potash Injection Schedules*, this page.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

For more information on cucurbit crop pest management, see the OMAFRA Publication *Ontario CropIPM*, Order No. AF141.

Diseases

See Table 9–31, *Activity of Fungicides on Cucurbit Diseases*, this page. Ratings in the shaded boxes indicate that the disease is listed on the product label. Always consult the product label for registered uses and additional use specifications. Use fungicides only for the crop and disease combinations listed on the product label. Additional information is provided in this table to assist the grower in choosing the best fungicide for control of diseases listed on the product label.

Table 9–31. Activity of Fungicides on Cucurbit Diseases

Common Name	Trade Name	Downy Mildew	Powdery Mildew	Angular Leaf Spot	Scab	Anthracnose	Alternaria	Gummy Stem Blight/Black Rot
chlorothalonil	Bravo	+	✓		✓	✓		
mancozeb	Dithane	+			✓	✓	✓	
	Manzate	+			✓	✓	✓	
	Penncozeb	+			✓	✓	✓	
cyazofamid	Ranman	✓						
propamocarb/chlorothalonil	Tattoo C	✓						
copper sulphate	Copper 53W	+		✓				
copper oxychloride	Copper Spray	+		✓				
	Parasol Flowable	+		✓				
pyraclostrobin	Cabrio	(✓)	✓			✓	✓	✓
potassium bicarbonate	MiiStop		✓					
boscalid	Lance WDG						✓	✓
captan	Maestro				✓	✓		
	Captan				✓	✓		
mandipropamid	Revus	(✓)						
fenamidone	Reason	(✓)						

✓ = control + = suppression () = on label but not considered effective or resistance documented

Table 9-32. Cucurbit Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL/ 100 kg seed	damping-off (<i>Pythium</i>)	For use on imported seed only. No domestic treatment.
Maxim 480 FS	fludioxonil	5.2–10.4 mL/ 100 kg seed	damping-off (<i>Fusarium</i> and <i>Rhizoctonia</i>)	
Thiram 75 WP	thiram	50 g/ 25 kg seed	seed decay and damping-off	

DAMPING-OFF AND ROOT ROTS

Use sterile soil or soil-less mix for growing seedlings. For identification and management information on these common vegetable diseases, see Chapter 8, *General Pests of Vegetable Crops*, on page 59. Also see Table 9-32, *Cucurbit Seed Treatments*, this page.

DOWNY MILDEW

Downy mildew is a serious disease of cucurbit crops. Cucumbers are the most susceptible to infection, however melons and other cucurbit crops can be affected by certain pathotypes of this disease. Downy mildew is wind borne and highly infectious. It can destroy an unprotected crop in less than 1 week.

Identification: Downy mildew–infected leaves develop pale green areas on the upper leaf surface. The corresponding lower leaf surface may be covered with a downy, grey-to-purple mould with black spores (sporangia). As the infection progresses, the lesions become yellow, then brown and necrotic.

In cucumbers, the lesions are often confined by the leaf veins and take on an angular appearance. During favourable environmental conditions, downy mildew can completely kill an unprotected crop within a week of the initial infection. Fruit from infected plants are usually undersized, deformed and unmarketable.

Development: Downy mildew is favoured by cool, wet or humid weather conditions. The heavy dewfalls common to the Great Lakes region support downy mildew infections in less than 2 hours of leaf wetness. Spore production is highest at temperatures of 15°C–20°C. Under favourable weather conditions, the pathogen will produce new inoculum in as little as 4 days.

Thresholds: Downy mildew must be managed preventatively. There are no thresholds.

Management Notes: Follow a basic 7–14-day preventative program using one of the broad spectrum fungicides listed in Table 9-33, *Cucurbit Downy Mildew Fungicide Recommendations*, next page. Initiate the program no later than vine development. If suitable environmental conditions exist during the early stages

of crop development, use a banded application to protect the young plants.

Cucumber growers should switch to one of the targeted downy mildew fungicides listed in Table 9-33, if downy mildew is identified in the Great Lakes region, **OR** during prolonged periods of cool, humid weather **OR** when there are cool night-time temperatures followed by heavy dewfall. If downy mildew has been identified in an area, maintain a strict 5–7-day fungicide schedule.

Apply all downy mildew fungicides preventatively. Always rotate between different fungicide groups.

Ensure good spray coverage. Select nozzles and set the air pressure to deliver a medium-to-fine droplet size. All fungicides should be applied in a minimum 340 L water/ha.

Growers who plant cucurbit transplants should ensure that the transplants are free from disease and grown in a greenhouse dedicated solely to transplant production. For cucumbers grown under plastic tunnels, apply a preventative fungicide immediately after transplanting and a second application as soon as the row covers are removed.

Note: The downy mildew–targeted fungicides will not provide protection against powdery mildew, scab and other cucurbit diseases. For these diseases, see Table 9-34, *Cucurbit Disease Control Recommendations*, on page 111.

POWDERY MILDEW

Identification: Initial symptoms develop on the undersides of older, shaded leaves. The white, powdery growth spreads to the upper leaf surface and down the petiole. Infected leaves and stems wither and die prematurely, impacting both yield and fruit quality.

Development: This disease does not overwinter in Ontario. Windborne spores usually arrive from the southern U.S. and Mexico in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C. Disease development slows when temperatures climb above 26°C.

Table 9-33. Cucurbit Downy Mildew Fungicide Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
Broadspectrum Preventative Fungicides						
Begin applications no later than vine development.						
chloronitrile (group M5)	chlorothalonil	Bravo 500	4.8 L	1.9 L	1	48-hr re-entry interval.
dithiocarbamate (group M3)	mancozeb	Dithane DG	1.1–3.25 kg	0.4–1.3 kg	14	24-hr re-entry.
		Penncozeb 80 WP				
		Manzate Pro-Stick	2.25–3.25 kg	0.9–1.3 kg		
Downy Mildew–Targeted Preventative Fungicides						
Begin applications when weather conditions favour downy mildew or if downy mildew is identified anywhere in the Great Lakes region.						
QIL (group 21)	cyazofamid	Ranman 400SC	150–200 mL in 200–600 L water	61–81 mL in 20–60 gal water	1	Maximum 6 applications/yr. Do not make sequential applications. 30-day plant back interval. 12-hr re-entry interval.
carbamate (group 28) chloronitrile (group M5)	propamacarb/ chlorothalonil	Tattoo C	1.8–2.7 L	0.7–1.1 L	2	Maximum 5 applications/yr. Do not make sequential applications. 48-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	5–15 L	2–6 L	0	Suppression only. Begin applications soon after emergence or transplanting.

¹ PHI = Pre-Harvest Interval (days).

¹ PHI = Pre-Harvest Interval (days).

Infections develop at relatively low humidity (<20%) levels, although humid weather conditions and heavy dews lead to more rapid disease development.

Thresholds: Begin applying protectant fungicides at the first sign of disease. Late July through August is usually the most critical powdery mildew control period.

Management Notes: There is a wide selection of powdery mildew-resistant varieties available for all types of cucurbit crops. Good spray coverage on both the upper and lower leaf surfaces is important. Apply all fungicides in a minimum of 340 L water/ha. See Table 9-34, *Cucurbit Disease Control Recommendations*, opposite page.

BACTERIAL WILT

Identification: Infected leaves develop dull green patches. As the vascular system becomes blocked with bacterium, the runners and, eventually, the whole plant become wilted. Plants ultimately turn yellow-brown and die.

Development: This disease overwinters in the stomachs of adult cucumber beetles. Beetles inject the bacterium into the plant as they feed. Cucurbit crops species and cultivars differ in their susceptibility to bacterial wilt. Generally speaking, cucumbers and melons are very susceptible.

Management Notes: Control cucumber beetle feeding to prevent the spread of this disease. See *Cucumber Beetles*, on page 113.

ANGULAR LEAF SPOT

Identification: Small, "water-soaked" lesions develop on infected leaves. These lesions expand in size until they are confined by the veins, resulting in an angular appearance. Affected areas turn brown, and the centres fall out, leaving small holes in the leaf.

Development: This bacterial disease is seed-borne. Bacteria also survive in infected crop residue. In wet conditions, it spreads rapidly across the field through splashing rainwater or machinery.

Thresholds: None have been established. Apply copper fungicides at the first sign of infection.

Management Notes: Angular leaf spot is more prevalent in pumpkins and squash. There is good varietal resistance available in cucumbers. Purchase pathogen-free seed; do not save seed from infected fields. A 2-year rotation away from cucurbit crops will reduce overwintering inoculum. See Table 9-34, *Cucurbit Disease Control Recommendations*, opposite page.

Table 9-34. Cucurbit Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ANGULAR LEAF SPOT						
inorganic (group M1)	copper sulphate	Copper 53W	2.5–3.0 kg	1–1.2 kg	1	Also controls anthracnose.
	copper hydroxide	Parasol Flowable	2.3–3.1 L	0.9–1.2 L	1	Cucumbers only.
	copper oxychloride	Copper Spray	4.0 kg	1.6 kg	1	Also controls anthracnose.
POWDERY MILDEW						
chloronitrile (group M3)	chlorothalonil	Bravo 500	4.8 L	1.9 L	1	48-hr re-entry interval.
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	226–340 g	3	Maximum 4 applications/yr. Do not make more than 1 application before alternating with a different fungicide family. 12-hr re-entry interval.
inorganic	potassium bicarbonate	MilStop	2.8–5.6 kg	1.1–2.25 kg	0	Suppression only. Ensure thorough spray coverage. 4-hr re-entry interval.
ALTERNARIA, ANTHRACNOSE, GUMMY STEM BLIGHT AND SCAB						
dithiocarbamate (group M3)	mancozeb	Dithane DG	1.1–3.25 kg	0.4–1.3 kg	14	Alternaria, anthracnose, gummy stem blight and scab. 24-hr re-entry.
		Penncozeb 80WP				
		Manzate Pro-Stick	2.25–3.25 kg	0.9–1.3 kg		
chloronitrile (group M5)	chlorothalonil	Bravo 500	4.8 L	1.9 L	1	Anthracnose and scab. 48-hr re-entry interval.
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	226–340 g	3	Alternaria, anthracnose and gummy stem blight. Use high rate for gummy stem blight. Maximum 4 applications/yr. Do not make more than 1 application before alternating with a different fungicide family. 24-hr re-entry interval.
carbamate (group 7)	boscalid	Lance WDG	460 g	186 g	0	Alternaria and gummy stem blight. Maximum 4 applications/yr. 4-hr re-entry interval.
phthalimide (group M4)	captan	Maestro 80DF	2.25–4.25 kg	0.9–1.7 kg	2	Cucumber only. Anthracnose and scab. Use low rate on young plants. Aerial applications permitted. 48-hr re-entry interval.
		Supra Captan 80 WDG				

¹ PHI = Pre-Harvest Interval (days).**SCAB, ANTHRACNOSE AND ALTERNARIA**

Identification: All these diseases cause leaf spotting and (occasionally) leaf distortion. Scab leaf lesions are small, numerous and pale yellow-to-white in colour. Scab fruit infections occur as large, sunken craters with corky margins.

Anthracnose leaf spots are dry and reddish brown, often with a lighter yellow border. Severely infected leaves become dry, cracked and ragged-looking. Anthracnose-infected fruit develop sunken lesions, varying in colour from red-brown to black. Under humid conditions, these lesions may develop masses of salmon pink spores. Watermelon are particularly susceptible to anthracnose infections.

Alternaria lesions start as small, yellow-to-brown flecks. As the flecks enlarge in size, concentric rings become apparent. On muskmelons, alternaria lesions may grow as large as 1 cm in diameter. These are somewhat smaller on watermelons. If left untreated, the lesions often grow together, causing the entire leaf to turn brown, wither and die. The resulting reduction in the leaf canopy often causes an increase in sunscald and damage to mature fruit.

These diseases may also develop on fruit in storage.

Development: Scab development favours cool, dry days interspersed with moisture and/or heavy dews. Field infection occurs at temperatures from

17°C–20°C. Melons may develop symptoms in storage at temperatures as low as 8°C.

Anthrachnose is a late-season disease. It prefers warm temperatures of 22°C–27°C and high relative humidity (100% for 24 hours).

Alternaria develops under a wide range of environmental conditions. It survives in a range of temperatures from 12°C–30°C.

Thresholds: None have been established. Scab infections may occur in all cucurbit crops. *Alternaria* and anthracnose are more commonly found in muskmelon and watermelon crops.

Management Notes: Follow a 2–3-year rotation away from all cucurbits. Avoid night-time overhead irrigation during cooler weather. See Table 9–34, *Cucurbit Disease Control Recommendations*, previous page.

GUMMY STEM BLIGHT (ALSO KNOWN AS BLACK ROT OR ALLIGATOR SKIN)

Identification: Circular tan-to-dark brown lesions develop between healthy green leaf veins. Infected leaves often curl inwards. Stem cankers often produce a gummy brown exudate, although other cucurbit diseases such as fusarium also produce stem exudates. Later in the season, gummy stem blight infections cause fruit decay, often accompanied by copious amounts of black spores (known as black rot.) On butternut squash, distinct circular bronze patterns (alligator skin) develop on the surface of infected fruit.

Development: Gummy stem blight survives on crop residue and in infected seed. Infections often occur in “hot spots” spreading out from a single infected seed.

Thresholds: None have been established. Apply fungicides at the first sign of foliar symptoms.

Management Notes: Follow a 2–3-year crop rotation and use certified, treated seed. Do not save seed from infected fields. See Table 9–34, *Cucurbit Disease Control Recommendations*, previous page.

FUSARIUM WILT

Identification: Fusarium wilt is a serious problem in muskmelons and an occasional problem in other cucurbits. Early-season fusarium wilt infections result in the damping-off of seedlings and transplants. Later infections cause the foliage to turn a dull grey-green and wilt, followed by a general yellowing and defoliation. *Fusarium* infection causes the vascular tissue to turn reddish-brown. A gummy exudate may form on the underside of infected vines.

Muskmelons from infected fields may develop raspberry-pink fungal growths on the underside of the fruit or at the blossom-end.

Development: Fusarium wilt may attack the plant at any stage. Outbreaks often follow periods of crop stress, including hot, dry weather conditions. Soil temperatures of 18°C–25°C support rapid disease progression. Cucurbit crops grown in slightly acidic soils (pH 5.0–5.5) may be more prone to fusarium infections. The fungal spores survive in the soil for many years.

Thresholds: None have been established. Foliar fungicides will not control this disease.

Management Notes: *Fusarium*-resistant cultivars are available. Several different races of *Fusarium* exist; look for varieties with multiple resistance genes.

Follow a 3–4-year rotation away from all cucurbits and use only sterile, soil-less mix for transplant production. Lime soil to a target pH of 6.0–6.5 and avoid over-fertilization, especially with fertilizers containing ammonium. Maintain adequate soil moisture levels, especially during fruit-set and sizing.

PHYTOPHTHORA BLIGHT

Identification: Phytophthora symptoms include foliar blight, fruit rot and stunting. The foliar blight/crown rot phase often starts at the growing point. Dark-green lesions form on the crown, eventually girdling it and causing the entire plant to turn brown, collapse and die.

Fruit infections begin as a large water-soaked lesion. White spores resembling powdered sugar develop on the surface of the lesion.

Development: Phytophthora spreads rapidly during warm, wet weather. Ideal conditions for infection are moist soils above 18°C and air temperatures between 24°C and 29°C. Phytophthora oospores live in the soil for up to 10 years.

Thresholds: None have been established.

Management Notes: Rotate fields for a minimum of 3 years away from all host crops (cucurbits, peppers, beans). Do not plant cucurbit crops in a field that has a history of phytophthora infections. Select well-drained fields. Minimize soil compaction and avoid excessive irrigation, especially in overhead systems. Disinfect farm equipment if travelling between infected and non-infected fields.

Table 9–35. Activity of Insecticides on Cucurbit Pests

Common Name	Trade Name	Cucumber Beetles	Aphids	Two-Spotted Spider Mite	Cutworms
imidacloprid	Admire	✓			✓
	Grapple	✓			✓
endosulfan	Thiodan 50 WP	✓	✓		
	Thionex 50 WP	✓	✓		
	Thiodan 4 EC	✓	✓		
kaolin clay	Surround WP	✓			
malathion	Malathion 25 W	✓	✓		
	Malathion 500 E	✓	✓		
dicofol	Kelthane 50 W			✓	
spiromesifen	Oberon Flowable			✓	
chlorpyrifos	Lorsban 4E				✓
	Pyrinex 480 EC				✓
carbaryl	Sevin XLR	✓			✓
spirotetramat	Movento		✓		

✓ = control

SEPTORIA LEAF SPOT

Septoria infections cause circular, white-to-light brown leaf lesions. Fruit lesions are raised and pimple-like. Septoria occurs only sporadically in Ontario. Muskmelons, pumpkins and winter squash are all susceptible. Septoria thrives under cooler, humid conditions of 16°C–19°C. It is more prevalent in early summer or late fall.

CUCUMBER MOSAIC VIRUS (CUMV)

This virus is transmitted by aphids and cucumber beetles. Transmission occurs very quickly (in less than 1 min). As a result, aphid control will not necessarily prevent an infestation. Use of resistant cultivars is the best available means of preventing yield losses.

Control perennial weeds in adjacent fencerows. Milkweed, ground cherry, pokeweed, chickweed and mother-wort are alternative hosts to the mosaic virus. See *Aphids*, on page 60, and *Viruses (General)*, on page 59.

Insects

See Table 9–35, *Activity of Insecticides on Cucurbit Pests*, this page. Ratings in the shaded boxes indicate that the insect is listed on the product label. Always consult the product label for registered uses and additional use specifications. Use insecticides only for the crop and insect combinations listed on the product label. Additional information is provided in this table to assist the grower in choosing the best insecticide for control of insects listed on the product label.

SEEDCORN MAGGOTS, WIREWORMS, MILLIPEDES, APHIDS, CUTWORMS

For identification and management information on these common vegetable insects affecting cucurbit crops, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–36, *Cucurbit Insect Control Recommendations*, next page.

CUCUMBER BEETLES

Identification: Striped cucumber beetles are 6–7 mm long with 3 black stripes. The less common, spotted cucumber beetle is slightly larger. While feeding damage can seriously harm seedlings, the main threat to cucurbit crop yield is the transmission of bacterial wilt.

Period of Activity: Cucumber beetles overwinter in crop refuse and fence rows. They usually arrive in cucurbit fields as the crop begins to emerge. They may be present in the field throughout the summer. However, early populations are generally the most damaging. Late-season feeding on the fruit may reduce marketable yields.

Thresholds: Treat when beetles exceed 0.5–1 per plant. Use the lower threshold on bacterial wilt-susceptible varieties. A follow-up spray may be necessary, as beetle emergence is often staggered.

Management Notes: Cucumber beetles tend to congregate in certain areas of the field, making them an excellent candidate for spot spraying. Cucurbit crops vary in their attractiveness to beetles. Zucchini

Table 9–36. Cucurbit Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
CUCUMBER BEETLES AND APHIDS						
Planting Treatment						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	Soil: 18 mL/ 100 m of row	Soil: 5.4 mL/ 100 ft of row	21	One application/yr applied in-furrow at planting or banded soon after planting. Depending on the row spacing, apply 0.74–1.16 L/ha (299–470 mL/acre). See the product labels for details. 24-hr re-entry interval.
		Grapple				
		Admire 240 F	Transplant water: 25 mL per 1,000 plants		21	One application/yr applied in-furrow at planting or banded soon after planting. Use 150 mL of water per plant. 24-hr re-entry interval.
		Grapple				
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0 kg	0.4 kg	2	Will also control squash vine borer. ²
		Thionex 50 WP	1.1 kg	0.44 kg	2	
		Thiodan 4 EC	1.5 L	0.6 L	2	
inorganic	kaolin clay	Surround WP	12.5–25 kg in 500 L water	5–10 kg in 45 gal water	0	Cucumber beetle control only. Use the high rate for the first application and the low rate for subsequent applications. Surround leaves a white residue on leaves and fruit. Do not apply close to harvest. Maximum 5 applications/yr.
organophosphate (group 1B)	malathion	Malathion 25 W	4.25 kg	1.7 kg	3	Cucumbers, squash, pumpkins.
			4.0–5.5 kg	1.6–2.2 kg	3	Melons.
		Malathion 500 E	1.8 L	0.7 L	3	Cucumbers, squash, pumpkins.
			2.25–2.75 L	0.9–1.1 L	3	Melons.
tetrionic and tetramic acid derivatives (group 23)	spirotetramat	Movento	220–365 mL	89–148 mL	1	Aphids only. Most effective on young stages of pest development. Slow activity; control may not be apparent for 2–3 weeks. 12-hr re-entry interval.
TWO-SPOTTED SPIDER MITE						
diphenylethane (group 3)	dicofol	Kelthane 50 W	1.0–1.25 kg	0.4–0.5 kg	7	Maximum 1 application/yr. Use high rate on large plants.
tetrionic and tetramic acid derivatives (group 23)	spiromesifen	Oberon	500–600 mL	202–243 mL	7	Apply before mite populations begin to build. Slow activity; control may not be apparent for 2–3 weeks. Maximum 3 applications/yr. 12-hr re-entry interval.
CUTWORMS						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1 L	60	Cucumbers only. Apply at 2–5 leaf stage. 24-hr re-entry interval.
		Pyrinex 480 EC				
carbamate (group 1A)	carbaryl	Sevin XLR	2.5 L	1 L	5	Climbing cutworms only. Do not apply during bloom.

¹ PHI = Pre-Harvest Interval (days).² Butternut squash is resistant to squash vine borer.

and pumpkins are highly attractive, cucumbers and melons less so. The more attractive species offer opportunities for trap cropping.

In-furrow insecticide applications often provide excellent cucumber beetle control. See Table 9–36, *Cucurbit Insect Control Recommendations*, this page.

Bee Warning

The insecticides listed in Table 9–36, *Cucurbit Insect Control Recommendations*, this page, are toxic to bees. Avoid spraying insecticides during bloom. If necessary, apply insecticides in the evening when bees are not working in the field. If hives are in the crop, remove them or close them off when treating the field.

TWO-SPOTTED SPIDER MITE

Identification: The adult mite is approximately 0.5–1 mm in length, barely visible to the naked eye. It is a translucent yellowish colour with two dark spots on the sides of its abdomen. Spider mites feed through sucking mouth parts. Injury first appears as a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress.

Period of Activity: Mite activity is most common in hot, dry conditions. They often move into cucurbits (especially watermelons) following wheat harvest.

Thresholds: None have been established. Melon plants are most susceptible to damage prior to first harvest.

Management Notes: Heavy rain or overhead irrigation often reduces mite populations to tolerable levels. See Table 9–36, *Cucurbit Insect Control Recommendations*, opposite page.

LEAFHOPPERS

High levels of leafhoppers occasionally appear in cucurbit crops after hay is cut in the spring. Feeding damage plugs the leaf veins causing V-shaped or circular yellow lesions on the leaf margins. This pest does not usually affect yields or crop quality. See *Potato Leafhopper*, on page 166, for more information.

SQUASH BUG

Identification: Squash bug eggs are laid in small clusters on the underside of the leaf. The bullet-shaped eggs are yellow when first laid, turning reddish-brown as they mature.

Squash bug nymphs have pear-shaped, pearly grey bodies with darker legs and antennae. Squash bug adults have flattened, tear-shaped bodies. They are brownish-grey with yellow-to-orange markings.

Squash bugs are commonly found in fairly large colonies with several different stages of development present at the same time.

Period of Activity: Adults emerge from overwintering sites in the spring and begin laying eggs in early June. Squash bugs may be present in cucurbit fields throughout the growing season. Populations often build to thresholds levels in late-summer to early-fall.

Thresholds: One egg mass per plant. Insecticides are most effective when targeted at small young nymphs.

Management Notes: Squash bugs like to hide in well-sheltered locations. Good weed control will help reduce the potential squash bug habitat in the field.

Nematode Control

For nematode control recommendations, see *Nematodes*, on page 63.

Curing and Storing Pumpkin and Squash

Windrowing squash and pumpkins in the field prior to storage often acts as a natural curing process. Room curing is not always necessary. Butternut and hubbard cultivars respond to this treatment, but storage life may be shortened. Curing acorn-type squashes decreases the storage life and eating quality. If deemed necessary, fruit may be cured for 10–20 days at 24°C–27°C.

Cucurbits vary significantly in their storage life expectancy. They are very susceptible to chilling injury, which appears after the fruit has been brought back to room temperature.

For pumpkins and winter squash, maintain storage temperatures between 10°C–15°C. Aim for 50%–70% relative humidity. High humidity levels will increase storage rots, while dry conditions will increase weight loss and shrinkage. Weight loss should be kept below 15%. See Table 9–37, *Pumpkin and Squash Storage Expectancy*, this page.

For information on storing cucumbers, melons and summer squash, see Table 6–3, *Storage Life for Fresh Vegetables in Commercial Storage*, on page 48.

Table 9–37. Pumpkin and Squash Storage Expectancy

Type	Storage Expectancy
Acorn	4–7 weeks
Pumpkin	8–12 weeks
Butternut	8–12 weeks
Buttercup	10 weeks
Turban	12 weeks
Hubbard	6 months

EGGPLANT

Production Requirements

Well-drained sandy loams, with relatively high organic matter levels and a pH of 5.5–6.5, are best for eggplant production. Eggplant require about 55–80 days from transplanting to harvest and 25–40 days from pollination to marketable fruit.

Recommended rotational crops: beans, brassica crops, cereal crops, corn, peas, soybeans

Do not rotate with: peppers, potatoes, tomatoes

Average Yields

Crop	per acre	per hectare
Eggplant	500 bu boxes graded product	1,250 bu boxes graded product

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

Row spacing:	90–120 cm	36–48 in.
In-row spacing:	45–60 cm	18–24 in.
Rate:	Approx. 200–300 g of seed will produce enough transplants for 1 ha (3–4 oz/acre).	

Plasticulture

Eggplant responds well to plastic mulches and row covers. However, eggplant is very susceptible to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature under the row cover regularly and ventilate when it reaches 35°C or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. For more information, see *Season Extension*, on page 34.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Apply up to 70 kg N/ha. Broadcast 35 kg N/ha and all the required phosphate and potash before planting. The remainder of the nitrogen should be side-dressed 3–4 weeks after transplanting.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, eggplant is unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, eggplant is unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Starter Solution

At transplanting, apply a high-phosphorus starter solution. Starter fertilizer is especially important when planting in cool soils. See *Starter Fertilizers for Vegetable Crops*, on page 6. Apply according to the recommendations in Table 9–38, *Eggplant Transplant Starter Solution Recommendations*, this page.

Table 9–38. Eggplant Transplant Starter Solution Recommendations

Soil Temperature	Starter Concentration ¹
below 18°C	Use full label rate as recommended.
18°C–27°C	Use half the recommended rate.
above 27°C	Starter not normally required.

¹ Under dry conditions or in sandy soils with less than 2% organic matter, use half the recommended rates.

Table 9–39. Eggplant Seed Treatment and Transplant Production Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate	Notes
DAMPING OFF, ROOT ROT				
phenylamide (group 4)	metalaxyl-M and S-isomer	Apron XL-LS	20–40 mL/ 100 kg of seed	Seed treatment. Pythium damping-off. One application per year. For import use only.
carbamate (group M3)	thiram	Thiram 75 WP	65–80 g/ 25 kg of seed	Seedbox treatment.
pthalamide (group M3)	captan	Maestro 80 DF	1.25 kg/ 1,000 L of water	Soil drench treatment. 48-hr re-entry interval.
		Supra Captan 80 WDG	Apply 50–85 L of solution per 100 m ² (1,076 ft ²).	
dithiocarbamate (group M2)	oxine benzoate	No-Damp	10 mL/ L of water	Soil treatment. Damping-off.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

To prevent damping-off, use sterile, soil-less mix for growing seedlings. Fungicides registered for greenhouse transplant production are listed in Table 9–39, *Eggplant Seed Treatment and Transplant Production Disease Control Recommendations*, this page. Also see Chapter 5, *Seeding and Transplanting*, on page 37.

VERTICILLIUM WILT

Identification: Infected plants develop extensive yellowing on the older leaves, followed by wilting and leaf drop. The yellowing may move in from the leaf margin in a characteristic “V” shape. Split the plant stem at the base to check for discolouration of vascular tissue.

Development: Verticillium wilt is a soil-borne disease. Symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes may further aggravate verticillium wilt.

Thresholds: Soil *Verticillium*, root knot and root lesion nematode counts, available from the Pest Diagnostic Clinic, University of Guelph, will help determine the need for control measures (see Appendix G, *Diagnostic Services*, on page 240).

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with solanaceous crops (tomatoes, peppers, potatoes), strawberries or raspberries. Keep fields clean of host weeds such as nightshades. Cultivars vary in tolerance to verticillium wilt. Soil fumigation may be required if *Verticillium* and nematode counts are high. See *Nematodes*, on page 63.

ANTHRACNOSE AND EARLY BLIGHT

Anthracnose and early blight are occasional diseases of eggplant. For identification, period of activity and management information, see *Anthracnose*, on page 205, and *Early Blight*, on page 207. See also Table 9–40, *Eggplant Disease and Insect Control Recommendations*, next page.

PHOMOPSIS BLIGHT

This disease causes circular, brownish spots on leaves and fruit. Black spots (pycnidia) develop in the centres of the lesions. Fruit lesions enlarge to 5–8 cm in diameter. Avoid planting in infested fields for 3 years.

Insects

CUTWORMS, TARNISHED PLANT BUG, WIREWORMS, APHIDS

For identification and management information on these common vegetable insects affecting eggplant, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–40, *Eggplant Disease and Insect Control Recommendations*, next page.

COLORADO POTATO BEETLE

Identification: Adults are orange with 10 black stripes on the wings. Larvae are red-to-orange with two rows of black spots along their sides.

Period of Activity: Beetles are present all season. However, feeding damage is a larger concern early in the season when plants are small.

Table 9-40. Eggplant Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ANTHRACNOSE AND EARLY BLIGHT						
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	227–340 g	0	Maximum 6 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 12-hr re-entry interval.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	71–127 g	0	Early blight only. Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	8–15 kg	3–6 kg	0	Early blight only. Suppression only. Also suppresses grey mould. Make first application when conditions are conducive to disease development. Repeat at 5–7-day intervals.
COLORADO POTATO BEETLE						
Transplant Treatment						
neonicotinoid (group 4)	imidacloprid	Admire 240 F Grapple	7–10 mL/ 100 m of row	2–3 mL/ 100 ft of row	70	Apply in-furrow at transplanting. Consult the label for application details. Do not apply a foliar neonicotinoid in the same season as a soil application. Alternate applications with other insecticide groups. 24-hr re-entry interval.
Foliar Treatments						
diamide (group 28)	chlorantraniliprole	Coragen	250–375 mL	101–152 mL	1	Early application on larval stages provides best control. 12-hr re-entry interval.
neonicotinoid (group 4)	imidacloprid	Admire 240 F Grapple	200 mL	81 mL	7	Maximum 2 foliar applications/yr, at least 5 days apart. Do not apply a foliar neonicotinoid in the same season as a soil application. Alternate applications with other insecticide groups. 24-hr re-entry interval.
carbamate (group 1A)	carbaryl	Sevin XLR	1.25 L	0.51 L	2	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1–2.25 kg	0.4–0.91 kg	2	
		Thionex 50WP	1.1 kg	0.4 kg	2	
spinosyn (group 5)	spinosad	Entrust 80 W	50 g	20 g	1	Maximum 3 applications/yr.
		Success 480 SC	83 mL	34 mL	1	Maintain a spray water pH of 6 or greater.
FLEA BEETLES AND APHIDS						
tetronic and tetramic acid derivatives (group 23)	spirotetramat	Movento 240 SC	220–365 mL	89–148 mL	1	Aphids only. Most effective on young stages. Has slow activity; control may not be apparent for 2–3 weeks. Under high pressure, a second application may be necessary 2 weeks later. 12-hr re-entry interval.
neonicotinoid (group 4)	thiamethoxam	Actara 25 WG	105 g	42 g	1	Do not apply a foliar neonicotinoid in the same season as a soil application. Alternate applications with other insecticide groups. 12-hr re-entry interval.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–2.25 kg	0.4–0.9 kg	2	
		Thionex 50WP	1.1 kg	0.4 kg	2	
carbamate (group 1A)	carbaryl	Sevin XLR	2.5 L	1.0 L	2	Flea beetles only.
TARNISHED PLANT BUG						
organophosphate (group 1B)	dimethoate	Cygon 480 Lagon 480 E	500–700 mL	202–283 mL	7	
MITES						
tetronic and tetramic acid derivatives (group 23)	spiromesifen	Oberon Flowable	500–600 mL	202–243 mL	7	Maximum 3 applications/yr. Apply before mite populations begin to build up. Control may not be apparent for 2–3 wks, especially under cool temperatures. 12-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).

Thresholds: None have been established. Chemical controls are most effective when they are applied to small larvae.

Management Notes: Rotate away from solanaceous crops. Colorado potato beetle overwinter in the fields of host crops. Avoid planting eggplant adjacent to fields that had host crops the previous year.

If scouting indicates a need, apply insecticide as a border spray or full treatment. In-furrow transplant water treatments are also available. See Table 9–40, *Eggplant Disease and Insect Control Recommendations*, opposite page.

Warning

In a number of areas, Colorado potato beetles have developed a strong resistance to certain insecticides. To slow development of further resistance, it is essential for all growers to rotate between chemical groups each time a spray is applied.

FLEA BEETLES

Identification: Small, dark beetles cause “shot-hole” feeding damage on leaves.

Period of Activity: Begin monitoring for flea beetles as soon as the transplants are set in the field.

Thresholds: None have been established.

Management Notes: If beetles or feeding are found on the plants, apply one of the insecticides listed in Table 9–40, *Eggplant Disease and Insect Control Recommendations*, opposite page.

Nematode Control

See *Nematodes*, on page 63, for nematode control recommendations.

Harvest and Storage

Harvest eggplant when they have reached marketable size but before the seeds begin to change colour. Fruits should be glossy and firm, not soft and spongy. Harvest by cutting the fruit from the plant. Handle carefully, as eggplant fruit bruises easily.

Store at 8°C–12°C and a relative humidity of 90%–95% for up to 1 week.

GARLIC

Production Requirements

Garlic produces good yields on well-drained, deep, fertile soils. Avoid planting into extremely heavy soil types. Low pH soils (5.0–5.5 or less) often result in very poor yields and plant stands. Garlic is a winter annual, planted in fall and harvested the following summer. Harvest begins when the leaf tops begin to dry, discolour and bend towards the ground.

Recommended rotational crops: carrots, parsnips, leafy greens

Do not rotate with: other allium crops

Average Yields

Crop	per acre	per hectare
Garlic	2,000–4,000 lb	2,000–4,500 kg

Cultivars

Cultivated garlic plants do not produce true seed. All garlic is propagated vegetatively. Two types of garlic are grown in Ontario — “hardneck” garlic, which produces seed stalks, or “softneck” garlic, which does not.

Growers should conduct their own field trials to evaluate varieties under local growing conditions. Consult the Garlic Growers Association of Ontario for seed sources (www.garlicgrowers.on.ca). See also Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

The optimum planting period is from September to late October. To estimate the planting date, growers should plan to plant at the average date for the first fall frost for their area. See Table 4–1, *Average Frost-Free Period in Climatic Zones of Ontario (1976–2005)*, on page 32.

	Metric	Imperial
Row spacing:	20 cm	8 in.
In-row spacing: ¹	7–12 cm	3–5 in.
Rate:	700–1,000 kg/ha	630–900 lb/acre
Depth of planting: ²	3–5 cm	1–2 in.

¹ Use wider spacing in lighter, drought-prone soils.

² Between soil surface and top of clove.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

On mineral soils, a total of 110 kg N/ha is required. Apply half the nitrogen as soon as the garlic plants begin to grow in the spring. Apply the rest of the nitrogen in 2–3 side-dress application at 3-week intervals.

On muck soils, apply a total of 120 kg N/ha. Apply 90 kg/ha prior to spring growth and the remainder as a side-dress application when the plants are 8–10 cm tall.

Phosphorus

Phosphorus requirements for garlic are similar to onions. Where the soil test values are 61 mg P per L soil (ppm) or higher, garlic is unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Potassium requirements for garlic are similar to onions. Where the soil test values are 181 mg K per L soil (ppm) or higher, garlic is unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Amend soil pH, phosphorus and potassium levels in the fall, prior to planting.

Irrigation

Garlic is shallow-rooted and sensitive to moisture stress. For most soil types, approximately 2.5 cm of water is required per week. On very coarse, sandy soils, as much as 5.0 cm is required weekly. For more information on irrigation scheduling, see Chapter 3, *Water Management*, on page 27.

Integrated Pest Management

Seed Treatments

Many garlic seed treatments intended for crop protection and disease reduction have been tested; however, none provide consistent results. Healthy, damage-free and disease-free planting stock is the best defence against damping-off and root rots. For more information on damping-off and root rots, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

Diseases

PENICILLIUM DECAY, GREEN MOULD

Identification: Infected cloves often fail to emerge in the spring or may produce weak, stunted plants that soon die. The fungus frequently sporulates on the surface of decaying cloves, producing bluish-green masses of spores.

Development: The fungus attacks cloves in late fall and early spring, prior to emergence.

Thresholds: None have been established.

Management Notes: Plant clonal cultivars known to be vigorous under Ontario growing conditions. Avoid damaging the seed cloves, especially during the cracking procedure. Many mechanized cracking devices cause excessive amounts of clove damage.

See Table 9–41, *Garlic Disease and Insect Control Recommendations*, next page.

FUSARIUM BASAL ROT, ALLIUM WHITE ROT

See *Fusarium Basal Rot* and *Allium White Rot*, on page 140. For allium white rot control options, see Table 9–41, *Garlic Disease and Insect Control Recommendations*, next page.

Insects

WIREWORMS

For identification and management information on wireworms affecting garlic, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59.

LEEK MOTH

Identification: In Central and Eastern Ontario, leek moth has caused significant damage to garlic. The larvae tunnel mines and create pinholes in the leaf tissue and the scapes, sometimes causing distortion. They occasionally attack the bulb. Damage to garlic cloves may predispose them to secondary bacterial or fungal diseases.

Larvae are yellowish-green with eight small, greyish spots on each segment and a pale-brown head capsule. They reach 13–14 mm at maturity. The reddish-brown

pupa is encased in a loosely netted cocoon. These cocoons are usually found on the leaves.

Period of Activity: There are three generations in Ontario, the first in June, the second in July and the third in late August. Information from Europe indicates the insect overwinters as an adult moth in sheltered areas and emerges in the spring when temperatures reach 9.5°C.

Thresholds: None have been established.

Management Notes: Monitor for leek moth using commercially available pheromone trapping systems. Install pheromone lures around the field edge in mid-to-late April and monitor until harvest. Insecticides applied 7–10 days following a peak flight of leek moth adults reduces overall damage.

ONION THRIPS AND ONION MAGGOTS

See *Onion Thrips* and *Onion Maggot*, on page 141. Control options are listed in Table 9–41, *Garlic Disease and Insect Control Recommendations*, next page.

Nematodes (Bulb and Stem)

Identification: This is a microscopic plant parasitic nematode that enters the plant through the roots or wounds on the bulb/clove. Once in/on a suitable host, it injects a toxin into the plant as it feeds, causing lesions and resulting in distorted growth.

Period of Activity: The bulb and stem nematode becomes active in the spring. The above-ground damage appear in mid-July through harvest.

Thresholds: 100 nematodes/kg of soil.

Management Notes: The key to management of this pest is prevention. Prevention includes planting clean seed and planting into uninfested soil. Take a soil nematode test before planting, use clean seed and follow a 3-year rotation with non-host crops. Once in the soil, the pest can be spread through irrigation water, on contaminated seed, equipment, humans and animals.

For nematode control information, see *Nematodes*, on page 63, and Table 8–1, *Nematodes Impacting Vegetable Crops in Ontario*, on page 64.

Harvest and Storage

Harvesting begins when the leaf tops begin to dry, discolour and bend towards the ground. Another indication of bulb maturity is the reduced thickness of the sheath leaves surrounding the bulb.

Table 9–41. Garlic Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
PENICILLIUM OR GREEN MOULD DISEASE						
dicarboximide (group 2)	iprodione	Rovral	4 g/L of water			Dip cloves into the Rovral suspension for 30 minutes immediately before planting.
BOTRYTIS, DOWNY MILDEW						
carboxamide + Qol (group 7 + 11)	boscalid + pyraclostrobin	Pristine WG	1.0–1.3 kg	0.4–0.5 kg	7	Use high rate for suppression of downy mildew. Maximum 6 applications/yr. Do not make sequential applications. 3-day re-entry interval.
Qol (group 11)	pyraclostrobin	Cabrio	0.84 kg	0.34 kg	7	Downy mildew only. Maximum 3 applications/yr. 24-hr re-entry interval, 72-hr re-entry interval for hand-thinning activities.
carboxylic acid amides group 40	mandipropamid	Revus	400–600 mL	162–243 mL	7	Downy mildew only. Use of a non-ionic surfactant (0.125% v/v) or mineral oil (1% v/v) is recommended.
biological	<i>Bacillus subtilis</i>	Serenade Max	3–4.5 kg	1.2–1.8 kg	0	Botrytis – suppression only. Begin applications at the first sign of disease or when conditions favour disease development.
			3–6 kg	1.2–2.4 kg	0	Downy mildew – suppression only. Begin applications at the first sign of disease or when conditions favour disease development.
ALLIUM WHITE ROT						
chlorophenyl (group 14)	dicloran	Botran 75 W	6.75–11.0 kg	2.7–4.4 kg		Spring Planting. Apply 1–2 weeks prior to planting and work into top 4 cm of soil.
			36.0–44.0 kg	14.5–17.8 kg		Fall Planting. Apply 1–2 weeks prior to planting and work into top 4 cm of soil.
LEEK MOTH						
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	188 mL in 500 L water	75.2 mL in 45 gal water	14	Maximum 3 applications/yr. 24-hr re-entry interval.
APHIDS, LEEK MOTH, THRIPS						
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	188 mL in 500 L water	76 mL in 45 gal water	14	Thrips and leek moth only. Maximum 3 applications/yr. 24-hr re-entry interval.
		Silencer 120 EC				
organophosphate (group 1B)	malathion	Malathion 500 E	1.1–2.75 L	0.4–1.1 L	3	
ONION MAGGOT						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	3.5 L in 1,000 L of water	1.4 L in 90 gal of water	50	Apply as a drench over the row on newly emerged plants (in the spring). 24-hr re-entry interval.
		Pyrinex 480 EC				

¹ PHI = Pre-Harvest Interval (days).

Storage conditions depend on the end use. Garlic for consumption (table stock) is best stored at 0°C–4°C with a relative humidity of 60%–70%. Avoid storing in higher humidity, as it creates an excellent environment for penicillium mould and root growth. Table stock stored at room temperature may dehydrate faster.

Store garlic intended for planting stock between 10°C and 20°C with 60%–70% relative humidity. Within

this temperature range, garlic stores from 4–8 months, depending on the variety.

For further information, see the OMAFRA Factsheets:

- *Garlic Production*, Order No. 97-007
- *Leek Moth – A Pest of Allium Crops*, Order No. 08-009.

HERBS

HERBS

Production Guidelines

Herbs are a diverse category of plants. Optimum production requirements will vary, depending on the plant itself and its use in the marketplace. Adequate light, water and soil nutrients are essential. Most herbs

prefer well-drained soil in a warm, sunny location. Heavy clay soils are generally not suitable.

See Table 9-42, *Culinary Herb Production Guidelines*, this page.

Table 9-42. Culinary Herb Production Guidelines

Crop	Type ¹	Expected Yield ² kg/ha/yr	Soil pH	Propagation	Planting Rate	Seeding Depth	Row Spacing	In-Row Spacing
Anise	A	500–900 (S)	6.0–7.5	seed	12–16.5 kg/ha 10.7–14.7 lb/acre	1 cm ½ in.	45–75 cm 18–30 in.	15–20 cm 6–8 in.
Borage	A	322 (D FL) 400–600 (S)	5.0–8.0	seed	12–17 kg/ha 10.7–15.2 lb/acre	0.6–2 cm ¼–¾ in.	15–60 cm 6–24 in.	5–60 cm 2–24 in.
Caraway	B	750–3,000 (S)	5.5–7.5	seed	10–18 kg/ha 9–16 lb/acre	0.6–4 cm ¼–1½ in.	25–30 cm 10–12 in.	20–30 cm 8–12 in.
Chervil	B	9,700 (F)	5.5–8.0	seed	15 kg/ha 13 lb/acre	0.6 cm ¼ in.	30 cm 12 in.	30 cm 12 in.
Chives	HP	9,000–19,000 (F)	6.0–8.0	seed	1.8 kg/ha 1.6 lb/acre	0.6 cm ¼ in.	30 cm 12 in.	10–15 cm 4–6 in.
Coriander/ cilantro	A	900–2,400 (S) 9,000–12,000 (F)	6.5–8.0	seed	15–33 kg/ha 13–29 lb/acre	0.6–4 cm ¼–1½ in.	15–30 cm 6–12 in.	3–10 cm 1–4 in.
Dill	A	3,000–5,000 (F) 1,000–1,600 (S)	5.6–6.5	seed	9–11 kg/ha 8–10 lb/acre	0.5–1 cm ¼–½ in.	Seed: 15–40 cm 6–16 in. Herb: 54–61 cm 20–24 in.	10 cm 4 in.
Fennel	A	14,000 (F) 1,000–1,500 (S)	7.0–8.0	seed	6.0 kg/ha 5.3 lb/acre	0.6–1.3 cm ¼–½ in.	30–40 cm 12–16 in.	20–30 cm 8–12 in.
Lavender	HP	2,900 (F FL) 300 (D FL)	6.5–7.5	cuttings	4,000–10,000 plants/ha 1,600–4,000 plants/acre	—	100–180 cm 40–70 in.	40–90 cm 16–36 in.
Lemon verbena	GA	Unknown	6.5	cuttings	10,000 plants/ha 4,000 plants/acre	—	100 cm 40 in.	100 cm 40 in.
Mint	HP	7,000–19,000 (F) 1,000–2,000 (D)	6.0–7.0	roots or cuttings	54,400 plants/ha 22,800 plants/acre	—	60 cm 24 in.	30 cm 12 in.
Oregano	HP	9,000–19,000 (F) 1,000–2,000 (D)	6.0–8.0	seed or division	43,500–109,000 plants/ha 17,400–43,600 plants/acre	0.5–1.0 cm ¼–½ in.	30–40 cm 12–16 in.	25–40 cm 10–16 in.
Parsley	B	10,000–20,000 (F) 1,000–2,000 (D)	6.0–7.0	seed	3–20 kg/ha 2.7–18 lb/acre	0.6 cm ¼ in.	30–50 cm 12–20 in.	15–20 cm 6–8 in.
Rosemary	GA	3,000 (F)	6.0–7.5	cuttings	20,000–40,000 plants/ha 8,000–16,000 plants/acre	—	50–100 cm 20–40 in.	50 cm 20 in.
Sage	HP	20,000–40,000 (F) 2,000–4,000 (D)	5.5–6.5	seed, cuttings, division	14–20 kg/ha 12–18 lb/acre	0.13 cm ⅛ in.	45–80 cm 18–31 in.	25–50 cm 10–12 in.
Summer savory	A	5,000–15,000 (F) 900–3,000 (D)	6.0–7.5	seed	30–35 seeds/m 9–10 seeds/ft	1–2 cm ½–¾ in.	30 cm 12 in.	15–20 cm 6–8 in.
Sweet basil	A	14,000 (F) 1,400 (D)	5.5–7.0	transplants	110,000 plants/ha 44,000 plants/acre	0.6–1.3 cm ¼–½ in.	30 cm 12 in.	30 cm 12 in.
Sweet marjoram	TP	4,000–9,000 (F) 300–500 (D)	6.5–7.5	seed, cuttings	—	0.3–0.6 cm ¼–¼ in.	30 cm 12 in.	20–25 cm 8–10 in.
Tarragon	HP	29,000 (F)	6.5	division	55,000–66,600 plants/ha 22,000–26,600 plants/acre	—	50–60 cm 20–24 in.	30–60 cm 12–24 in.
Thyme	TP	1,100–2,200 (F)	4.5–8.0	seed, cutting, division	110,000 plants/ha 44,000 plants/acre	0.6 cm ¼ in.	30–40 cm 12–16 in.	20–40 cm 8–16 in.

— = Adjust planting depth according to the size of the cutting or root division.

¹ Type: A = annual, B = biennial, HP = hardy perennial, TP = tender perennial, GA = grown as an annual under Ontario conditions

² Expected Yield: F = fresh, FL = flowers, D = dried, S = seeds

Table 9–43. Herb Seed Treatments

Trade Name	Active ingredient	Rate	Pests Controlled	Notes
Maxim 480 FS	fludioxonil	5.2–10.4 mL/ 100 kg seed	damping-off, seedling blights (<i>Pythium</i> & <i>Rhizoctonia</i>)	For use by commercial seed treatment facilities only. Treatment of seeds only.

Planting density, row width, weed control and fertilizer decisions are made based on the size of the roots and foliage, the market requirements and equipment limitations. Select disease-free and weed-free planting sites. Consider including heavy metals in the pre-plant soil analysis.

Propagation

There are three main propagation methods for herbs:

Seed: Sow directly in the field or into trays for transplanting. Most herbs perform poorly from bare root transplants. Not all herbs transplant well. See Table 9–43, *Herb Seed Treatments*, this page.

Cuttings: Take 8–10 cm cuttings from the tips of vegetative growth or from the stem. Remove leaves

and buds from the bottom half of the cutting, dip in rooting hormone and stick into sterilized horticultural sand or vermiculite. Cover to keep humidity high.

Divisions: Division is usually performed in the spring. Divide crowns (the junction of the root and stem) into clumps. Cut rhizomes into nodes or root clusters that contain nodes. Separate bulbs into clusters.

Integrated Pest Management

There are limited options for chemical pest control in herb crops. Pest control measures often include cultural practices aimed at prevention and elimination of the pest problem. For more information on general cultural practices impacting pest populations, see Chapter 7, *Integrated Pest Management*, on page 51.

Table 9–44. Insects and Diseases Affecting Herb Crops

Crop	Pests	Notes
Anise	cercospora leaf spot, rust, sclerotinia stem rot	Avoid crop rotations with other umbelliferous crops.
Borage	alternaria leaf spot, sclerotinia white mould	
Caraway	aster yellows, sclerotinia stem rot, ascochyta blossom blight	Avoid crop rotations with other umbelliferous crops.
Chervil	See <i>Parsley</i> , on page 128.	
Chives	aphids, leafhoppers, leafminers, tarnished plant bug, downy mildew, rust	Also see pests of onions, leeks and shallots.
Coriander/ cilantro	aphids, grasshoppers, whitefly, mites, seedling rot, damping-off, puccinia rust, aster yellows, pseudomonas, sclerotinia white mould, botrytis leaf blight, xanthomonas	Rotate out of umbelliferous crops (carrot, parsnip, celery, etc.) for at least 2–3 years.
Dill	phoma leaf blight, alternaria leaf blight, pythium root rot, leaf spots (cercospora, septoria), aster yellows, aphids, leafhoppers	Do not save seed. If phoma is present, do not re-plant dill for at least 3 years.
Fennel	aphids, caterpillars	
Lavender	spittle bug, septoria leaf spot, phytophthora crown and root rots, fusarium/phytophthora/verticillium wilts, alfalfa mosaic virus, powdery mildew	Serious pest problems may occur if lavender is planted in poorly drained soil.
Lemon verbena	aphids, mites	
Mint	leafhoppers, tarnished plant bug, four-lined plant bug, leafminers, caterpillars, grasshoppers, puccinia rust, powdery mildew, verticillium wilt	Rust and verticillium are the most important pests in many mint-growing areas.
Oregano	aphids, leafhoppers, grasshoppers, spittle bugs, tarnished plant bug, leafminers, mites, thrips, nematodes, pythium crown and root rot, rust	
Parsley	aphids, caterpillars, alternaria leaf scorch, leaf spot (alternaria, phoma or sclerotinia), powdery mildew, pythium root rot, aster yellows, various viruses	Rotate out of umbelliferous crops (carrot, parsnip, celery, etc.) for at least 2–3 years.
Rosemary	aphids, leafhoppers, tarnished plant bug, thrips, mites, alternaria leaf blight, botrytis, root rot, powdery mildew	
Sage	aphids, leafhoppers, caterpillars, grasshoppers, leafminers, spittlebugs, tarnished plant bug, mites, slugs, downy mildew, powdery mildew, root rot, rust	
Summer savory	leafhoppers, pythium root rot, verticillium wilt	
Sweet basil	aphids, leafhoppers, caterpillars, tarnished plant bug, Japanese beetle, alternaria leaf blight, sclerotinia white mould, fusarium wilt, powdery mildew	Large variability exists between basil varieties in susceptibility to insect and disease damage.
Sweet marjoram	damping off, botrytis, alternaria leaf spot	
Tarragon	leafhoppers, tarnished plant bug, fusarium root rot, rust	
Thyme	leafhoppers, grasshoppers, nematodes, botrytis grey mould	Nematodes can cause stunting and wilt that is easily misdiagnosed.

Table 9-45. Herb Disease and Insect Control Recommendations

Group	Common Name	Trade Name	Rate per hectare	Rate per acre	PHI ¹	Notes
GREENHOUSE TRANSPLANT DISEASE CONTROL						
biological	<i>Gliocladium catenulatum</i>	Prestop	100 g/20 L water (0.5% solution) treats 10 m ²			Only for use on oregano, basil, parsley, thyme and dill in the greenhouse. Suppression of damping-off caused by <i>Pythium</i> spp. and <i>Rhizoctonia solani</i> when applied at planting and pythium crown and root rot with repeat applications. 4-hr re-entry interval. Only for suppression of <i>Fusarium oxysporum</i> on basil in the greenhouse. 4-hr re-entry interval.
			200 g/20 L water (1% solution) treats 10 m ²			
GREENHOUSE TRANSPLANT INSECT CONTROL						
soap	potassium salts of fatty acids	Opal Insecticidal Soap		8 L/ 400 L water	0	Controls aphids, mites and whiteflies. Caution: Do not apply to new seedlings and transplants without first determining phytotoxicity.
APHIDS, WHITEFLIES, SPIDER MITES						
soap/ pyrethroid	potassium salts of fatty acids + pyrethrins	Safer's Trounce	5 L	2 L	1	Apply in 100 L of water/ha. Repeat as required, according to application intervals specified on label. Maximum 8 applications per season.
soap	potassium salts of fatty acids	Opal Insecticidal Soap	14–38 L	5.7–15.4 L	0	Mix 8 L product in 400 L water and apply dilute solution at a rate of 700–1,900 L/ha. Repeat at 1–2 week intervals to a maximum of 3 consecutive applications. Additional applications may be made if previous experience has shown this will not cause phytotoxicity. Caution: Do not apply to new seedlings and transplants without first determining phytotoxicity.
CABBAGE LOOPER						
biological (Group 11)	<i>Bacillus thuringiensis</i>	Dipel 2X DF	275–550 g	110–220 g	0	Apply to control young larvae. Maximum 5 applications/yr.
		Bioprotec CAF	1.4–2.8 L	0.5–1.1 L	0	Apply in a minimum of 300 L water/ha. Allow 5–10 days between applications. Maximum 5 applications/yr.

¹ Pre-harvest interval (days).

Insect and disease pests vary greatly between different species of herbs. Table 9-44, *Insects and Diseases Affecting Herb Crops*, previous page, summarizes some of the major pests to be found on herbs. Listed pests have either been observed in Ontario or are known from areas with similar growing conditions.

For more information on common insect and disease pests affecting herbs and other vegetables, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

For control recommendations for pests affecting herbs, see Table 9-45, *Herb Disease and Insect Control Recommendations*, this page. Note that pest control products for parsley, chervil and chives are not included in this chapter. See *Parsley*, on page 128, and *Onion*, on page 135. For a complete list of herbs included in the herb and spice crop group, see sidebar, this page.

The herbs crop group includes angelica, balm/lemon balm, basil, borage, burnet, camomile, catnip, chervil (dried), chive (dried), Chinese chive (dried), clary, coriander (cilantro, chinese parsley) (leaf only), costmary, cilantro (leaf only), curry (leaf only), dill (dillweed), horehound, hyssop, lavender, lemongrass, lovage (leaf only), marigold, marjoram, nasturtium, oregano, parsley (dried), pennyroyal, rosemary, rue, saffron, sage, savory (summer and winter), sweet bay (bay leaf), tansy, tarragon, thyme, wintergreen, woodruff and wormwood.

Harvest and Storage

If practical, harvest in early morning after the dew has dried from the crop and before the sun dissipates the essential oils; leaves should be clean and free of dust and soil. Do not completely strip the stems of the entire leaf crop, as remaining leaves are necessary to keep the plants growing.

Crop-Specific Comments

Anise

Seed when soil is 21 °C into rich, well-drained soil. Irrigate frequently until seed formation. Anise needs

HERBS

130 days frost-free. When seeds begin to turn grey, cut plants 10–12 cm above ground. Harvest seeds on the main stem first. Swath and thresh after 4–5 days. Dry at 29°C–48°C to 10%–12% moisture.

Borage

Borage needs regular irrigation. Borage flowers 60 days after seeding. Pick blossoms as they open. Swath when the largest seeds are at the proper stage and the stems are still green. Seeds shatter easily when swathed. Dry at 32°C–48°C in the dark to 9.5% moisture. Do not keep product longer than 1 year.

Caraway

Harvest when 75% of the seeds are brown. Combine to a height of 30–40 cm. Mature seed shatters easily. Dry at 29°C–48°C to 10% moisture. Store seeds in an aeration bin.

Chervil

Chervil grows best in partial shade during hot periods and may need protection from the wind. Harvest leaves frequently to encourage growth. Fresh chervil is preferred by many markets. Dry at 29°C–43°C to maintain colour.

Chives

Divide chive plants after 3 years of production and plant in a new location. Harvest by cutting 6–7 cm above the soil surface, up to 3–4 times per year. Fresh tips are sold 15–20 cm long. Remove any flower stems or wilted leaves. Flash freeze or freeze-dry for best quality.

Coriander/cilantro

Hot weather induces flowering in cilantro. Cut coriander when 40% of the fruit is ripe. Thresh 4–5 days later. Dry at ambient temperatures using aeration until 18% moisture is reached. Finish drying at 80°C–90°C. Cut cilantro just before flowering. Refrigerate leaves immediately after harvest.

Dill

Dill can be invasive. It performs best on cool growing conditions and may require windbreaks. Harvest seeds 7–9 days after petal drop. Cut during a dew to reduce shattering. Harvest leaves just as the flowers open. Dry leaves at 32°C to avoid browning. Pick umbels as plants flower and the seed is still green.

Fennel

Fennel will hybridize with dill. It performs best on low organic matter soils. Swath seeds when they are waxy-ripe and thresh 5–7 days later. Dry at 29°C–43°C and separate seeds from stems after drying. Harvest flower

stalks just before bloom and use fresh. Harvest leaves fresh throughout the season.

Lavender

Good soil drainage is essential for overwintering success. Harvest flowers at full bloom for potpourri. Harvest flowers at the end of bloom for oil. Cut stems below the first set of leaves. Dry in the dark at temperatures below 32°C to preserve colour.

Lemon Verbena

High soil fertility levels will decrease flavour. Keep in pots 2 years before setting in the field. Harvest leaves before bloom. Strip leaves individually from the plants. Dry on screens at 32°C–48°C.

Mint

Mint is highly invasive. Rotate with a small grain every 3 years. Leaves can be picked any time for fresh or dry market, up to 2 times per year. For fresh or dry market, harvest leaves individually or gather in bunches. Dry leaves at 37°C–40°C. For oil, pick just as flowering begins, swath and allow plants to wilt before processing.

Oregano

Harvest in the first year at the start of bloom. Cut plants at a 15–20-cm height, 2–4 times per year. Dry at 29°C–43°C. Renovate oregano every 3–5 years.

Parsley

Plant into a rich, deep soil. Begin harvest approximately 75 days after seeding. For fresh market, harvest manually and bunch. Wash and cool immediately to 0°C–2°C and store at high relative humidity.

Rosemary

Rosemary will not overwinter in the field. Plant into dry, well-drained sites. Cut when flowers begin to bloom. Never harvest more than half the plant. Dry at temperatures below 40°C in a well-ventilated, dark area. Rosemary can also be freeze-dried.

Sage

Harvest leaves and tops in late summer or early fall. Late harvests can decrease winter survival. Cut above the woody portion of the stem. For oil, cut at full bloom. Separate leaves from stems immediately after harvest. Dry in a well-aerated area at 37°C. Sage plantings will last 4–5 years before becoming too woody.

Summer Savory

Summer savory may need irrigation until established. It performs best on well-drained soils. Cut just above

the lowest branches, up to 2 times per year. Dry in the field after cutting. Screen dry material to remove sand.

Sweet Basil

Sweet basil is sensitive to frost. Cut stalks just before flowering, leaving at least 4 sets of leaves. Harvest fields twice a year, beginning at 80 days after planting. Dry for 2 weeks at ambient temperatures (preferably 29°C–48°C). Leaves may turn brown at high temperatures.

Sweet Marjoram

Pick the leaves just as the first flowers open. For oil, harvest during flowering. Leave 10–12 cm of stubble for regrowth. Hang to dry at 54°C to 14% moisture or freeze dry. Yields decrease as the plant ages. With adequate winter protection, 3–5 years of production is possible.

Tarragon

Grow tarragon on well-drained soils. Cut in the first year when plants are 40–60 cm high. Two cuttings are possible in following years. Cut plants 15 cm above the ground. Dry leaves at 60°C. Tarragon does not set seed.

Thyme

Garden thyme prefers well-drained soil. Two cuttings per years are possible at flowering and in late summer. Thyme can be grown as an annual or short-lived perennial. Older plantings become woody. Some winter protection may be required in colder regions. Dry leaves at ambient temperatures in the shade to preserve colour.

LETTUCE, ENDIVE & PARSLEY

Production Requirements

Lettuce, endive and parsley are cool-season vegetables. They grow best at temperatures between 13°C–18°C. On mineral soils, production is limited to the transplanted early crop and the seed-sown late crop. On muck soils, leafy green crops may be produced throughout the growing season. The preferred soil pH is 6.1–6.5 on mineral soils and 5.5 on muck.

Recommended rotational crops: beans, celery, corn, onions, peas, cereal crops

Do not rotate: into fields with a history of sclerotinia white mould

Average Yields

Crop	per acre	per hectare
Head lettuce (crisphead, butterhead)	800–1,000 cases (25,000–40,000 lb)	2,000–2,500 cases (28,000–45,000 kg)
Cos lettuce (romaine)	1,000–1,200 cases (25,000–40,000 lb)	2,500–3,000 cases (28,000–45,000 kg)
Leaf lettuce	12,000–16,000 lb	13,500–18,000 kg
Endive / escarole	12,000–16,000 lb	13,500–18,000 kg
Parsley	700–1,100 bu boxes	1,500–2,500 bu boxes

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Planting, Seeding and Spacing

Germination occurs even at temperatures as low as 2°C for lettuce and 4°C for parsley. Germination is delayed at soil temperatures above 27°C.

Use coated or pelleted seed with a precision seeder to ensure a more uniform stand. This also reduces thinning costs and provides higher percentages of cut at harvest time.

Seeding time is important on both muck and mineral soils. Immature plants will recover from a frost event. The wrapper leaves on mature heads are very susceptible to frost and can only be marketed at a lower grade if they are damaged.

Table 9–46. Lettuce, Endive and Parsley Spacing and Seeding Rates

	Metric (cm)		Imperial (in.)	
	Row Spacing	In-Row Spacing	Row Spacing	In-Row Spacing
Butterhead and leaf	30	20–30	12	8–12
Crisphead	40	30–35	16	12–14
Endive	40	20–30	16	8–12
Parsley	30–40	10–15	12–16	4–6

Properly hardened transplants, when set in the field in the early spring, can tolerate temperatures as low as –7°C. See *Transplanting*, on page 39.

Plant approximately 1–2 kg of seed/ha. See Table 9–46, *Lettuce, Endive and Parsley Spacing and Seeding Rates*, this page.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

Broadcast and incorporate the recommended preplant nitrogen with the required potash and phosphate. On mineral soils, side-dress the remaining nitrogen 3 weeks after transplanting or thinning the crop. See Table 9–47, *Lettuce Nitrogen Recommendations*, this page.

Table 9–47. Lettuce Nitrogen Recommendations

Soil Type	Actual N kg/ha
Mineral soils	
Preplant broadcast	55
Side-dress	55
Total	110
Muck soils	
Preplant broadcast ¹	120

¹ Reduce to 100 kg/ha (107 lb/acre) for mid- to late-season plantings.

Table 9-48. Lettuce Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Ridomil Gold 1G	metalaxyl-M	25 kg/ha (10 kg/acre)	damping-off (<i>Pythium</i>)	Apply with seed in-furrow. Use 115 g/100 m of row. Do not use on transplants.
Apron XL LS	metalaxyl-M	20-40 mL/ 100 kg seed	damping-off (<i>Pythium</i>)	
Thiram 75 WP	thiram	90 g/ 25 kg of seed	seed decay, seedling blight, damping-off	Seed box treatment.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, lettuce crops on both muck and mineral soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), see Table 1-10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, lettuce crops on both muck and mineral soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1-12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Calcium

Under hot, dry conditions, lettuce may benefit from foliar applications of calcium to prevent tipburn symptoms. See *Calcium*, on page 15, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Copper

Copper (Cu) deficiency may show up on organic (peat and muck) soils. Mix copper with the fertilizer and apply at 14-29 kg Cu/ha on newly cultivated muck. Subsequent applications may be made every 2 or 3 years at about one-third the rate recommended for new muck. See *Copper*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Manganese

Manganese-deficient lettuce appears as yellowing between the veins, which remain dark green. Manganese deficiency usually shows up on slightly acid or alkaline muck, peat and dark-coloured sandy soils. Soil application is not recommended for manganese because of the large amounts required. If a deficiency is identified, apply foliar manganese sprays starting after thinning or transplanting. For more information, see *Manganese*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

See OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*, for a comprehensive guide to IPM for lettuce.

Diseases

DAMPING-OFF AND ROOT ROTS

For more information on damping-off and root rots, see Chapter 8, on page 59. For lettuce crops, also see Table 9-48, *Lettuce Seed Treatments*, this page.

BOTRYTIS GREY MOULD

Identification: White-to-grey downy fungi first develop on older, outer leaves. This rapidly reduces the leaf to a water-soaked, slimy mass of tissue and causes the plant to completely collapse.

Development: Grey mould overwinters in the soil and on plant debris. Rapid fungal growth occurs in damp weather with temperatures of 18°C-23°C.

Thresholds: None have been established.

Table 9–49. Lettuce and Parsley Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
BOTRYTIS GREY MOULD						
Greenhouse-Grown Seedlings						
dithiocarbamate (group M3)	ferbam	Ferbam 76 WDG	2 kg/ 1,000 L water	0.8 kg/ 9 gal water		Lettuce only. Spray seedlings before transplant.
Field Application						
dicarboximide (group 2)	iprodione	Rovral	1.5 kg	0.6 kg	4	Lettuce only. Maximum 4 applications/yr. Start after thinning, apply at 7-day intervals. 12-hr re-entry interval.
carboxamide (group 7)	boscalid	Lance WDG	285 g	114 g	14	Lettuce only. Maximum 2 applications/yr. 4-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	4–12 L	1.6–4.8 L	0	Suppression only. Apply after emergence or transplant and continue on 7–10 day intervals.
DOWNY MILDEW						
phenylamides + dithiocarbamate (group 4 + M3)	metalaxyl-M + mancozeb	Ridomil Gold MZ 68 WP	2.5 kg	1 kg	14	Lettuce only. Maximum 3 applications/yr.
dithiocarbamate (group M3)	zineb	Zineb 80 W	1.7–2.3 kg	0.68–0.92 kg	10	Lettuce only.
phosphonate (group 33)	fosetyl-al	Aliette WDG	2.8 kg	1.12 kg	7	Lettuce only. Maximum 5 applications/yr. 12-hr re-entry interval.
carboxylic acid amides (group 40)	mandipropamid	Revus	400–600 mL	162–243 mL	1	Downy mildew. Maximum 4 applications/yr. The use of a non-ionic adjuvant (0.125% v.v) is recommended.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade Max	3–6 kg	1.2–2.4 kg	0	Suppression only. Begin applications at the first sign of disease or when conditions favour disease development. Also registered for powdery mildew.
LETTUCE DROP (SCLEROTINIA WHITE MOULD)						
dicarboximide (group M3)	vinclozolin ²	Ronilan EG	1.1 kg	0.44 kg	28	Lettuce only. Maximum 3 applications/yr. ² 12-hr re-entry interval. Apply 12 days after thinning on seeded crop or 5–7 days after transplanting. Second and third applications may be made at 10-day intervals. Note that a 15-m buffer zone must be maintained between sprayed areas and aquatic systems such as ponds and ditches.
carboxamide (group 7)	boscalid	Lance WDG	385 g	154 g	14	Maximum 2 applications/yr. 4-hr re-entry interval.
chlorophenyl (group 14)	dicloran	Botran 75 W	2.3–3.75 kg	0.9–1.5 kg	14	Lettuce only. Maximum 2 applications/yr.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade Max	3–6 kg	1.2–2.4 kg	0	Suppression only. Begin applications at the first sign of disease or when conditions favour disease development.

¹ PHI = Pre-Harvest Interval (days).

Management Notes: Fungicides can be effective, but it is very difficult to get adequate coverage of the lower leaves, where infection first occurs. Grow on raised beds to increase air movement and decrease disease pressure. Follow a good crop rotation with cereals and other non-host crops. See Table 9–49, *Lettuce and Parsley Disease Control Recommendations*, this page.

DOWNY MILDEW

Identification: Infection usually begins on the mature leaves and spreads inward toward the central leaves. Chlorotic (yellowish) or pale-green areas appear on the upper surface of the leaves. White, velvety areas are found on the lower leaf surface. Infected tissue usually dies.

Development: The fungus overwinters in wild lettuce plants and on crop debris. Spores are spread by wind or splashing rain. For germination to occur, the leaf surface must be moist. This is a cool-season disease.

The optimum temperature for infection occurs from 15°C–20°C. The time from infection to the production of new spores varies from 5–18 days.

Thresholds: None have been established.

Management Notes: Select resistant cultivars and follow a 2–3-year crop rotation. Plowing infected residue may reduce the soil inoculum. See Table 9–49, *Lettuce and Parsley Disease Control Recommendations*, opposite page.

LETTUCE DROP (SCLEROTINIA WHITE MOULD)

Identification: Lettuce drop (wilting of the entire plant) is most often observed as plants approach maturity. The limpness of the entire plant resembles the symptoms of grey mould. Cottony-white fungi develop on the underside of the lower leaves. Black sclerotia are often embedded within it.

Development: The long-lived sclerotia overwinter in the soil and on plant debris. Lettuce drop is most prevalent during cool, wet weather.

Thresholds: None have been established.

Management Notes: Follow a 2–3-year rotation with non-susceptible crops such as onions, beets or spinach. Good drainage and growing lettuce on raised beds increases air movement around the plants. Flooding infested land for 3–4 weeks causes the breakdown of sclerotia and may reduce soil populations. See Table 9–49, *Lettuce and Parsley Disease Control Recommendations*, opposite page.

SEPTORIA LEAF SPOT

Identification: Greyish-brown spots with yellow margins appear on leaves and petioles. Small, black specks (pycnidia) are often noticeable in the centre of the lesions.

Development: Septoria is spread by infected seed, crop residues and on weed hosts. Spores germinate at temperatures above 12°C. Infection requires the presence of water or high humidity (greater than 90% relative humidity) for 24 hours.

Management Notes: Seed-borne infections decrease in 2-year-old (or older) seed. Bury infected crop residues and follow a 2–3-year rotation to reduce soil-borne infections.

RHIZOCTONIA BOTTOM ROT

Rust-coloured sunken lesions appear on the midrib of lower leaves. Bottom rot is most commonly observed on mineral soils. The fungus is active during warm,

humid weather. Rotate with legumes, cereals, grasses or other non-host crops. Plant in areas with good soil drainage and avoid fields with a history of bottom rot. Growing lettuce on raised beds will improve air circulation near the base of the plant, where infection is likely to begin.

CORKY ROOT ROT

Yellow lesions appear on the roots. These lesions enlarge until the entire tap root is brown, rough and cracked. Corky root rot builds up with continual lettuce cropping and is more severe in warm conditions.

Allow sufficient time between lettuce crops for the plant residues to decompose completely. Avoid applying excessive amounts of nitrogen, especially urea. Raised beds and reduced irrigation are recommended to encourage deep rooting. Resistant cultivars are available.

BACTERIAL WILT, DRY LEAF SPOT

Bacterial wilt is a seed-borne pathogen. Water-soaked, wedge-shaped spots form along the leaf margins. Spots may become olive coloured. Bacterial wilt requires a wound, such as frost injury, sand blasting or mechanical damage, to infect healthy plants. Excessive nitrogen or overhead irrigation may increase disease levels. Follow good sanitation practices in all greenhouse areas used for transplant production.

LETTUCE MOSAIC VIRUS

Leaves develop chlorotic, yellow spotting. Plants grown from infected seed or infected early in their development have pale green-to-yellow mottled leaves. Lettuce mosaic is primarily seed-borne. However, it can also be transmitted by aphids.

Mosaic-indexed or mosaic-tested seed is available from most sources. This seed is produced in special areas where it is carefully checked to ensure that it is virtually free from seed-borne mosaic. Control aphids, which spread the disease from infected lettuce plants. Weeds such as groundsel, shepherd's-purse and lamb's-quarters are alternate hosts.

ASTER YELLOWS

Transmitted by the aster leafhopper, aster yellows causes a bright yellowing and twisting of leaves. Infected crisphead types suffer poor head formation. Secondary bacterial rots often follow aster yellows. See *Aster Leafhopper*, on page 97, for control recommendations.

Table 9-50. Lettuce, Endive and Parsley Aphid, Cutworm and Tarnished Plant Bug Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
APHIDS — AT-PLANTING TREATMENTS						
neonicitinoid (group 4)	imidacloprid	Admire 240 F	10.2 mL/ 1,000 plants	21		Transplant tray plug drench. Do not follow transplant drench with soil or foliar treatments. 24-hr re-entry interval.
		Alias 240 EC				
		Grapple				
		Admire 240 F	650 mL	263 mL	21	Soil application (field drench). Apply in 2,000 L water/ha (180 gal/ acre) directly over the row. Do not follow soil drench application with foliar treatments. 24-hr re-entry interval.
		Alias 240 EC				
		Grapple				
APHIDS — FOLIAR TREATMENTS						
neonicitinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	22–35 g	7	Also controls pea leafminer. Maximum 5 applications/yr. Alternate applications with other insecticide families. 12-hr re-entry interval.
	imidacloprid	Admire 240 F	200 mL	81 mL	7	Maximum 2 applications per crop. Do not make a foliar imidacloprid application following a plug treatment or soil drench application. 24-hr re-entry interval.
		Alias 240 EC				
		Grapple				
tetramic acid derivative (group 23)	spirotetramat	Movento 240 SC	220–365 mL	89–148 mL	3	Most effective on young stages. Has slow activity; control may not be apparent for 2–3 weeks. 12-hr re-entry interval.
chlorinated cyclodiene (group 2 A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	Head lettuce only. Maximum 3 applications/yr.
		Thionex 50WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	7	Head lettuce only. Maximum 4 applications/yr. 24-hr re-entry interval. Workers must wear gloves in the field for 2 weeks following application.
	diazinon ¹	Diazinon 500 E	1.1 L	0.4 L	10	Lettuce only.
					14	Parsley only.
	dimethoate	Cygon 480	0.7 L	0.3 L	7	Leaf lettuce only. Do not use on head lettuce.
		Lagon 480 E				
	methamidophos	Monitor 480	1.1–2.25 L	0.4–0.9 L	14	Head lettuce only. 48-hr re-entry interval.
naled ²	Dibrom	1.1–1.65 L	0.4–0.66 L	4	Lettuce, endive only. 48-hr re-entry interval.	
CUTWORMS						
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83 mL	34 mL	3	Head lettuce only. 24-hr re-entry interval. Maximum 3 applications/yr. Dark-sided and white cutworms only.
		Silencer 120 EC				
	cypermethrin	Ripcord 400 EC	175 mL	71 mL	21	Do not disturb soil for 5 days after treating.
	permethrin	Pounce	180–390 mL	73–158 mL		Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application. Use high rate on large larvae, dry soils or muck soils. 12-hr re-entry interval.
		Perm-UP				
Ambush 500 EC		140–300 mL				
TARNISHED PLANT BUG						
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83 mL	34 mL	3	Head and leaf lettuce. Maximum 3 applications/yr. See the label for a full list of leafy greens this product is registered for use on. 24-hr re-entry interval.
		Silencer 120 EC	83 mL	34 mL	3	Head lettuce only. Maximum 3 applications/yr. 24-hr re-entry interval.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	Head lettuce only.
carbamate (group 1A)	carbaryl	Sevin XLR	2.5–5.25 L	1–2.1 L	5	Head lettuce only.

¹ PHI = Pre-Harvest Interval (days).² Control of aphids with naled and diazinon has been inconsistent in many areas.

Table 9-51. Lettuce, Endive and Parsley Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ASTER LEAFHOPPER						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	125 mL	51 mL	14	Lettuce only. Maximum 4 applications/yr. 12-hr re-entry interval.
		UP-Cyde 2.5 EC	200 mL	80 mL	14	
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	5	Head lettuce.
					21	Leaf lettuce, endive, parsley.
organophosphate (group 1B)	malathion	Malathion 500 E	1.4–3 L	0.6–1.2 L	14	Head and leaf lettuce.
inorganic	kaolin clay	Surround WP	12.5–25 kg in 500 L water	5–10 kg in 45 gal water	0	Lettuce and parsley. For early applications, use the higher rate per 250 L water. Surround WP forms a barrier film, which acts as a broad spectrum protectant that may decrease damage from aster leafhoppers.
PEA LEAFMINER						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	35 g	7	Maximum 5 applications/yr. Do not apply more than once every 7 days. 12-hr re-entry interval.
cyromazine (group 17)	cyromazine	Citation 75 WP	188 g in 200 L water	76 g in 18 gal water	7	Maximum 5 applications/yr. See the label for a full list of leafy greens this product is registered for use on. 12-hr re-entry interval.
CABBAGE LOOPER						
biological (group 11)	<i>Bacillus thuringiensis</i>	Dipel 2X DF	275–550 g	111–222 g	0	Lettuce & parsley only. 275 g/ha rate maximum for parsley.
		Thuricide HPC	2.0–4.25 L	0.8–1.7 L	0	Lettuce only.
spinosyn (group 5)	spinosad	Success 480 SC	182 mL	74 mL	1	Maximum 3 applications/yr. Maintain a spray pH of 6 or greater. See the label for a full list of leafy greens this product is registered for use on.
		Entrust 80 W	109 g	44 g	1	
	spinetoram	Delegate WG	140–200 g	57–80 g	1	Use high rate for heavy infestations or large larvae. Maximum 3 applications/yr. 12-hr re-entry.
diamides (group 28)	chlorantraniliprole	Coragen	250 mL	100 mL	1	Maximum of 4 applications/yr.
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83 mL	34 mL	3	Head lettuce only. Maximum 3 applications/yr. 24-hr re-entry interval.
		Silencer 120 EC				
chlorinated cycloidiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	Head lettuce only. Maximum 3 applications/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	14	
carbamate (group 1A)	methomyl	Lannate	0.51–1.0 kg	0.2–0.4 kg	7	Lettuce only.
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	7	Head lettuce only. Maximum 4 applications/yr. 24-hr re-entry interval. Workers must wear gloves in the field for 2 weeks following application.
	methamidophos	Monitor 480	1.1–2.25 L	0.4–0.9 L	14	Head lettuce only. 48-hr re-entry interval.
	naled	Dibrom	1.1–1.65 L	0.4–0.7 L	4	Lettuce & endive only. 48-hr re-entry interval.
TWO-SPOTTED SPIDER MITES						
tetrionic and tetramic acid derivatives (group 23)	spiromesifen	Oberon Flowable	500–600 mL	202–243 mL	7	Maximum 3 applications/yr. Apply before mite populations begin to build up. Control may not be apparent for 2–3 weeks, especially under cooler temperatures. 12-hr re-entry interval. If harvesting or pruning, 48-hr re-entry.

¹ PHI = Pre-Harvest Interval (days).

Insects**APHIDS, CUTWORMS, TARNISHED PLANT BUG**

For identification and management information on these common vegetable insects affecting lettuce, endive and parsley, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–50, *Lettuce, Endive and Parsley Aphid, Cutworm and Tarnished Plant Bug Control Recommendations*, on page 132.

ASTER LEAFHOPPER

The aster leafhopper transmits aster yellows. See the aster yellows (AYI) calculation in *Aster Leafhopper*, on page 97.

Treat when the AYI equals 20–25 for head lettuce or 30–35 for romaine. See Table 9–51, *Lettuce, Endive and Parsley Insect Control Recommendations*, previous page.

PEA LEAFMINER

Pea leafminer (PLM) larvae feed between the upper and lower surface of the leaves, reducing photosynthetic capacity. The mines also affect marketability and provide an entrance for disease organisms. Leafminers are most likely to attack head and leaf lettuce types. For more information, see *Leafminers*, on page 103. See Table 9–51, *Lettuce, Endive and Parsley Insect Control Recommendations*, previous page.

CABBAGE LOOPER

While this is a rare problem, the cabbage looper can cause sporadic damage in lettuce, endive and parsley. Use a 5% infestation control threshold. See Table 9–51, *Lettuce, Endive and Parsley Insect Control Recommendations*, previous page.

Nematode Control

See *Nematodes*, on page 63, for nematode control recommendations.

Harvest and Storage

Lettuce and leafy green crops are usually harvested by hand and packed into cartons in the field. Mechanical harvesters are available.

Leafy green crops are not adapted to long-term storage. To achieve a 2–3-week storage life, maintain a temperature of 0°C and 95%–100% relative humidity. Vacuum cooling or hydrocooling can help maintain a fresh appearance. Cracked ice used in or around packages will help maintain quality during transportation.

For more information on storage, see Chapter 6, *Food Safety and Storage*, on page 45.

For more information on pest management in leafy green crops, consult the following OMAFRA Factsheets and publication:

- *The Aster Leafhopper and Aster Yellows*, Order No. 98-057
- *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053
- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Caterpillar Pests of Crucifer Crops*, Order No. 99-035
- *Tarnished Plant Bug Damage on Vegetable Crops in Ontario*, Order No. 98-025
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

ONIONS, LEEKS & SHALLOTS

Production Requirements

Allium species (onions, leeks, shallots, chives, etc.) grow in a wide range of soil types. They tend to grow best on mineral soils with a pH range of 5.8–7.0 and on muck soils with a pH range of 5.0–6.0. Dry onions (cooking and Spanish) mature in 75–120 days. Green bunching onions mature in 60–70 days, and leeks mature in 105–125 days.

Recommended rotational crops: carrots, parsnips, leafy greens

Do not rotate with: other allium crops

Average Yield

Crop	per acre	per hectare
Dry onions (cooking, Spanish)	600–1,000 #50 bags	1,500–2,500 #50 bags
Bunching (green) onions	900–1,200 lb (4,000 dozen)	1,000–1,500 kg (10,000 dozen)
Leeks	500 cases ¹	1,250 cases ¹
Shallots	9–12 tons	20–27 tonnes

¹ 1 case = 24 bunches of 3 leeks each.

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

In Ontario, both summer and autumn leeks are grown. Two types of shallots are available: the French-Italian (brownish-red skin) and the Welsh shallot (green shallot).

Spacing and Seeding

The minimum soil temperature for seed germination is 2°C. Ideal planting conditions occur when the soil temperatures reach 10°C. The optimum planting depth ranges from 0.5–2.5 cm. Use shallow seeding on heavy mineral or crust-prone soils. In drier soil and in areas where wind and water erosion are problems, sow seeds at a depth of 3–4 cm.

To achieve an earlier crop, dry bulb onions can be grown in plug trays and transplanted into the field when soil conditions permit. Transplants have some advantages in managing disease and weeds, as well as producing an earlier crop. See *Transplanting*, on page 39. See Table 9–52, *Allium Species Spacing and Seeding Rates*, this page.

Irrigation

Allium species have shallow, limited root systems. The critical water-use period lasts up to, and including, the bulb formation stage. When overhead irrigating, do not permit the available soil water to fall below 60%. For drip-irrigated onion crops, use an irrigation threshold of 85% available soil water. The plants should receive 2.5 cm of water a week, either as rainfall or irrigation. Irrigation after bulb maturity may not be beneficial and may reduce yield and/or quality.

Irrigation may not be necessary on deep muck soils. Maintain the water table at 85 cm below the soil surface.

Table 9–52. Allium Species Spacing and Seeding Rates

Crop	Metric			Imperial		
	Row Spacing (cm)	In-Row Spacing (cm)	Rate (kg/ha)	Row Spacing (in.)	In-Row Spacing (in.)	Rate (lb/acre)
Dry bulb (cooking and Spanish)	35–43	2.5–3.5	4–4.5	14–17	1–1.5	3.5–4
Bunching (green)	30–38	1–2.5	7	12–15	0.5–1	6
Dry bulb transplants (cooking and Spanish)	35–43	10–12.5	1.7–3.5 ¹	14–17	4–5	1.5–3 ¹
Leeks (transplants)	60–90	10–15	1.1–2.2 ¹	24–35	4–6	1–2 ¹
Pickling onions			35–45			31–40
Shallots	45–60	7.5–10	220–330 ²	18–24	3–4	200–300 ²

¹ Listed seeding rates will produce enough transplants for 1 ha (1 acre).

² Bulbs.

Table 9–53. Onion Nitrogen Recommendations

Soil Type	Actual N kg/ha
Mineral Soils	
Apply up to	110
Muck Soils	
Preplant	90
Side-dress	30
Total	120

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

On shallow muck soil or soils with a high proportion of mineral soil, band 200 kg/ha monoammonium phosphate (MAP), applied 5–7.5 cm below the seed. Reduce the broadcast fertilizer by 22 kg/ha nitrogen and 96 kg/ha phosphate.

Leeks require higher amounts of nitrogen than onions, normally around 200 kg N/ha, applied in three instalments: one preplant and two side-dressings.

See Table 9–53, *Onion Nitrogen Recommendations*, this page.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, onions grown on both muck and mineral soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, onions grown on both muck and mineral soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Copper

Copper (Cu) deficiency occurs on organic (peat and muck) soils. Bulbs show poor-coloured skins. Copper may be mixed with the fertilizer and applied at 14–29 kg Cu/ha on newly cultivated muck. Subsequent applications may be made every 2 or 3 years at about one-third the rate recommended for new muck.

Manganese

Manganese deficiency shows up as a yellowing between leaf veins. Foliar applications of manganese sulfate are recommended, starting when plants are about 15 cm tall with 1.5–2.75 kg manganese sulfate/ha in 300 L water, repeated for 4–5 sprays, 10 days apart. Use the low rate on small plants, increasing the rate as the season progresses. Soil application is not recommended.

See *Manganese*, on page 18, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Molybdenum

Molybdenum deficiency may occur when onions are grown on moderate-to-strongly acid muck soils. A seed treatment has proven beneficial. The treatment is accomplished by dissolving 15 g of sodium molybdate in 45 mL of water. Spray this solution from an atomizer bottle on 2.3 kg seed spread thinly on a plastic sheet. Do not use excessive water, as this can cause the chemical to penetrate the seed embryo and cause injury. Mix seed thoroughly and let dry. See *Molybdenum*, on page 19, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Zinc

Zinc-deficient plants develop yellow-striped foliage. They become stunted, twisted and bent. Deficiencies occur mainly with shallow muck soils or where calcareous subsoils are mixed with the muck. See *Zinc*, on page 19, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Table 9-54. Activity of Fungicides on Onion Diseases

Active Ingredient	Trade Name	Botrytis Leaf Blight	Damping-Off/ Root Rots	Downy Mildew	Onion Smut	Purple Blotch
chlorothalonil	Bravo 500	✓				
mancozeb	Dithane DG	✓		✓	✓	✓
	Manzate Pro-Stick	✓		✓		✓
	Penncozeb 80 WP	✓				
zineb	Zineb 80 W	✓		✓		✓
metalaxyl-M/mancozeb	Ridomil Gold MZ 68 WP			✓		
pyraclostrobin/boscalid	Pristine WG	✓		+		✓
boscalid	Lance WDG	✓				✓
pyraclostrobin	Cabrio EG			✓		✓
iprodione	Rovral	✓				✓
fosetyl-al	Aliette WDG			✓		✓
cyprodinil/fludioxonil	Switch 62.5 WG	✓				+
<i>Bacillus subtilis</i>	Serenade Max	+		+		
oxine benzoate	No-Damp		✓			

✓ = control

+ = suppression

Integrated Pest Management

See OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*, and *Ontario CropIPM* (www.ontariocropIPM.ca) for a comprehensive guide to IPM for onions.

Diseases

See Table 9-54, *Activity of Fungicides on Onion Diseases*, this page. Ratings in the shaded boxes indicate that the disease is listed on the product label. Always consult the product label for registered uses and additional use specifications. Use fungicides only for the crop and disease combinations listed on the product label.

Additional information is provided in this table to help the grower choose the best fungicide for control of diseases listed on the product label.

DAMPING-OFF AND ROOT ROTS

For identification and management information on damping-off and root rot diseases affecting onions, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9-55, *Onion Seed and Greenhouse Treatments*, this page.

To manage damping-off and root rots in greenhouse transplants, see Table 9-56, *Allium Disease Control Recommendations*, next page.

Table 9-55. Onion Seed and Greenhouse Treatments

Active Ingredient(s)	Trade Name	Insects and Diseases			Notes
		Onion Maggot	Damping-Off	Onion Smut	
cyromazine	Governor 75 WP	✓			Imported seed only. Only on muck soils. Do not plant treated seed in the same field in consecutive years. Pre-harvest interval for green onions is 60 days; 100 days for dry onions.
metalaxyl-M	Apron XL LS		✓		For use in commercial seed-treatment plants only.
thiram	Thiram 75 WP		✓		Seed box treatment.
carathiin/thiram	Pro-Gro			✓	Pro-Gro treated seed may be stored for up to 4 months.
oxine benzoate	No-Damp		✓		Greenhouse treatment. Apply 10 mL of No-Damp per L of water. For preventative control, water the soil before seeding.

Table 9–56. Allium Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
SMUT						
dithiocarbamate (group M3)	mancozeb	Dithane DG	4.4–8.8 kg	1.8–3.5 kg	100	Apply in-furrow at seeding time. Use high rate only where smut pressure is high.
DOWNY MILDEW, BOTRYTIS LEAF BLIGHT, PURPLE BLOTCH						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.4–4.8 L	1–1.9 L	7	Dry bulb. Botrytis leaf blight only. Maximum 3 applications/yr. 48-hr re-entry interval.
					14	Green bunching. Botrytis leaf blight only. Maximum 5 applications/yr.
dithiocarbamate (group M3)	mancozeb	Dithane DG	2.25–3.25 kg	0.9–1.3 kg	10	Labelled for dry onions only. 24-hr re-entry.
		Manzate Pro-Stick				
		Penncozeb 80 WP				
	zineb	Zineb 80 W	0.85–3.3 kg	0.34–1.3 kg	7	Onions only.
phenylamide + dithiocarbamate (group 4 + M3)	metalaxyl-M + mancozeb	Ridomil Gold MZ 68 WP	2.5 kg	1 kg	7	Onions only. For downy mildew only. Apply before first outbreak of disease. Maximum 3 applications/yr.
QoI + carboxamide (group 11 + 7)	pyraclostrobin + boscalid	Pristine WG	1.0–1.3 kg	404–526 g	7	Use high rate for suppression of downy mildew. Maximum 6 applications/yr. Do not make sequential applications. 3-day re-entry interval.
carboxamide (group 7)	boscalid	Lance WDG	475 g	192 g	7	For purple blotch and botrytis leaf blight. Maximum 6 applications/yr. Apply before disease develops. Do not apply more than 2 sprays before rotating to a different fungicide family. 4-hr re-entry interval.
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	226–340 g	7	For purple blotch and downy mildew only. Maximum 3 applications/yr. Do not apply more than 2 sprays before rotating to a different fungicide family. 24-hr re-entry interval. 72-hr re-entry for hand-thinning activities.
dicarboximide (group 2)	iprodione	Rovral ²	0.75–1.5 kg in 300–500 L water	303–607 g in 30–50 gal water	15	Onions and leeks only. Maximum 4 applications/yr. 12-hr re-entry interval.
phosphonate (group 33)	fosetyl-al	Aliette WDG	2.8 kg	1.1 kg	7	Onions only. For downy mildew and purple blotch. Maximum 5 applications/yr. 12-hr re-entry interval.
phenylpyrroles + anilino- pyrimidines (group 12 + 9)	cyprodinil + fludioxonil	Switch 62.5 WG	775–975 g	313–394 g	7	Dry bulb and green onions only. For botrytis leaf blight and suppression of purple blotch. Maximum 3 applications/yr. Do not make more than 2 sequential applications. 12-hr re-entry interval.
carboxylic acid amides (group 40)	mandipropamid	Revus	400–600 mL	161–243 mL	7	Downy mildew. Maximum 4 applications/yr. The use of a non-ionic adjuvant (0.125% v.v) is recommended.
biological	<i>Bacillus subtilis</i>	Serenade Max	3–4.5 kg	1.2–1.8 kg	0	Botrytis suppression. Begin applications at the first sign of disease or when conditions favour disease development.
			3–6 kg	1.2–2.4 kg	0	Downy mildew suppression. Begin applications at the first sign of disease or when conditions favour disease development.

¹ PHI = Pre-Harvest Interval (days).² Rovral when tank-mixed with label rates of mancozeb will control botrytis leaf blight and downy mildew. Apply on a preventative basis. This tank-mix combination will help reduce the chance of resistance to Rovral.

BOTRYTIS LEAF BLIGHT

Identification: White, oval-shaped spots with silvery halos develop on infected leaves. Lesions are 1–5 mm long. Severely infected leaf tips die back. Infection is more likely to occur if the leaves are injured, bruised or starting to die-back.

Development: Botrytis leaf blight typically develops after mid-June when temperatures and leaf-wetness periods are sufficient for infection to occur. Optimum conditions for infection are 12 hours of leaf wetness at 15°C–18°C. Levels of infection are reduced at temperatures above 27°C.

Thresholds: A forecasting model called BOTCAST helps to predict botrytis leaf blight outbreaks. If BOTCAST is not available, use a threshold of 1 active lesion/leaf on dry bulb and Spanish onions. For green bunching onions, the threshold is 0.5 active lesions/leaf. After the first spray is applied, subsequent sprays should be applied 8 days later if the probability of rain is greater than 30%.

DOWNY MILDEW

Identification: Infections usually occur in patches within the field. A violet or greyish growth develops, and the tissue dies quickly, resulting in straw-coloured lesions and eventual plant death.

Development: This disease is more common in cool, wet seasons. Infection occurs when the foliage remains wet for 2–6 hours at 3°C–14°C. The incubation period lasts for 10–16 days. A relative humidity of 95% or greater will also promote further infections.

Thresholds: A forecasting model called DOWNCAST helps to predict downy mildew outbreaks. If DOWNCAST is not available, apply protective fungicides during cool and humid weather conditions.

PURPLE BLOTCH

Identification: The 1–3 cm spots are brown with reddish-purple margins. There may be a yellow zone around the lesions. Infected leaves may be weakened and easily blown over.

Development: Infection occurs when warm weather, 18°C–30°C, coincides with prolonged leaf wetness. Weaker plants or those affected by other diseases are at highest risk.

Thresholds: None have been established.

Botrytis, Downy Mildew and Purple Blotch Management Notes

All three of these diseases overwinter in crop debris. Dormant *Botrytis sclerotia* can remain viable for many years. Practice a 2–3-year crop rotation and remove cull onions from the field. See Table 9–56, *Allium Disease Control Recommendations*, opposite page.

ONION SMUT

Identification: Most muck soils are infested with onion smut spores. When untreated, resulting losses may be as high as 50%–80%. Infected plants appear thickened, darker and slightly twisted. Cut leaves expose a mass of black teliospores on the inside. Most plants die within 3–4 weeks of infection.

Development: The smut spores are long-lived and may last up to 20 years in the soil. Infection occurs at 10°C–12°C within 2–3 weeks of seeding.

Thresholds: None have been established.

Management Notes: The only practical means of controlling onion smut is the use of a seed treatment or fungicide in-furrow. See Table 9–55, *Onion Seed and Greenhouse Treatments*, on page 137, and/or Table 9–56, *Allium Disease Control Recommendations*, opposite page.

BOTRYTIS NECK ROT AND SMUDGE

Identification: *Botrytis*-infected bulb tissue becomes greyish. Mould may also develop. Black sclerotia eventually appear in affected tissue. The smudge fungi form black concentric rings near the neck and on the outer scales of the bulb.

Development: Both botrytis neck rot and smudge are most commonly found on bulbs after harvest, but they can appear on maturing bulbs in the field. The fungi of both diseases can survive in the soil for several years. Smudge prefers warm, wet weather. *Botrytis* infections occur during cool, wet conditions.

Management Notes: Follow a 2–3-year crop rotation and remove cull onions from the field. Proper curing and drying reduces disease development in storage. Artificial heat curing may reduce problems in humid areas of the province. Grade out onions with thick necks, nicks or bruises prior to storage. Most commercial onion cultivars are susceptible to neck rot, particularly Spanish and white types. Yellow and red-skinned onions are resistant to smudge.

ALLIUM WHITE ROT

Identification: Foliar symptoms include yellowing, wilting and stunted plants. White fungal growth with small pinhead-sized sclerotia may be visible at the base of the plant. The fungus causes a watery rot and disintegration of infected bulbs. This disease is not always present at harvest but may show up in storage.

Development: The sclerotia and mycelium overwinter in soil and plant debris. Soil infested with allium white rot is spread by machinery, animals, pallet boxes, wind and water. Warm soil temperatures, greater than 24°C are less conducive to allium white rot.

Management Notes: Allium white rot can survive in the soil for many years. Remove cull onions from field areas and wash all implements used in infested fields. Sclerotial germination stimulants (such as garlic oil, diallyl disulphides, etc.) can significantly reduce white rot.

PINK ROOT

Identification: Infected roots have a pinkish-red colour and eventually turn purplish-black. The root system may be substantially reduced, causing the plant to turn yellow, wither and become stunted. Even when present in the soil, pink root will not affect the yields of healthy crops, grown on healthy soils.

Development: The fungus can survive in the soil for several years in the absence of host plants. It mainly attacks onion roots when soil temperatures rise to 26°C.

Management Notes: Problem fields will require a rotation of several years out of allium crops.

FUSARIUM BASAL ROT

Identification: Early symptoms include the yellowing of leaves and tip dieback. As the disease progresses, the whole plant may collapse. The basal plate of the onion becomes pinkish-brown. Secondary bacterial rots may also develop. If the infection occurs late in the season, the symptoms may not show up until the onions are in storage.

Development: Basal rot occurs under warm soil temperatures. A temperature of 29°C is optimum for disease development. Basal rot is not prevalent every year in all areas. It is often observed on Spanish onions growing in Southwestern Ontario.

Management Notes: Follow a long crop rotation and use disease-free transplants.

LEEK RUST

Identification: This is an occasional disease of leeks. Rust-coloured spores develop on the upper and lower leaf surfaces. Healthy plants are less susceptible to leek rust.

Development: Rust occurs during high humidity and low rainfall conditions.

Management Notes: Follow a 2–3-year crop rotation and use only certified seed. Plant into well-drained soils. Do not grow onion and leek crops in the same vicinity.

SOFT ROT, SLIPPERY SKIN AND SOUR SKIN

Identification: These diseases are characterized by a watery rot and strong smell. Onions with slippery skin may appear sound on the surface. However, the inner rotted portions will slide out through the neck when squeezed. Sour skin first appears as tan or brown rotted leaves followed by a soft rot near the neck.

Development: Infections begin during wet field conditions. Tissues damaged by onion maggot or other diseases are most prone to infection.

Management Notes: Minimize all types of injury to bulbs (sunscald, bruising and mechanical damage) and provide good storage conditions. Do not put diseased or damaged onions into storage. Avoid using overhead irrigation when the crop is approaching maturity, especially with Spanish types. Harvest onions only when fully mature.

IRIS YELLOW SPOT VIRUS

Identification: Virus symptoms include bleached or straw-coloured diamond-shaped lesions. Some active lesions have a yellow halo surrounding a green island of leaf tissue. Lesions often appear on the youngest leaves, where the majority of thrips feeding occurs. Infected plants can produce good quality bulbs, however, under stressful conditions, plants will prematurely lodge and bulb sizing ceases.

Development: Onion thrips, the only known vector of this disease, are prevalent in all onion-growing regions in Ontario. Thrips favour hot, dry weather conditions and are present throughout the growing season. Disease symptoms tend to appear later in July or into August in onion crops grown from seed or transplant. Onions grown from sets and garlic often display symptoms earlier in July.

Thresholds: None have been established.

Table 9-57. Activity of Insecticides on Onion Pests

Common Name	Trade Name	Cutworms	Leek Moth	Onion Maggot Larvae	Onion Maggot Flies	Onion Thrips
chlorpyrifos	Lorsban 15G			✓		
	Lorsban 4E	✓				
	Pyrifos 15G			✓		
	Pyrinex 480 EC	✓				
cypermethrin	Ripcord 400 EC	✓			✓	✓
	UP-Cyde 2.5 EC	✓			✓	✓
diazinon	Diazinon 50W				✓	✓
	Diazinon 500				✓	✓
naled	Dibrom				✓	✓
cyhalothrin-lambda	Matador 120 EC		✓			✓
	Silencer 120 EC		✓			✓
deltamethrin	Decis 5 EC					✓
permethrin	Pounce	✓				

✓ = control

Management Notes: Manage onion thrips populations throughout the season to mitigate the spread of this disease. Good sanitation practices, removal of cull and volunteer onions and weeds are also important to help reduce the incidence of iris yellow spot virus.

For more information on onion diseases, see the OMAFRA Factsheet, *Identification of Diseases and Disorders of Onions*, Order No. 95-063.

Insects

See Table 9-57, *Activity of Insecticides on Onion Pests*, this page. Ratings in the shaded boxes indicate that the insect is listed on the product label. Always consult the product label for registered uses and additional use specifications. Use insecticides only for the crop and insect combinations listed on the product label. Additional information is provided in this table to assist the grower in choosing the best insecticide for control of insects listed on the product label.

CUTWORMS, WIREWORMS

For identification and management information on these common vegetable insects affecting onions, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9-58, *Allium Insect Control Recommendations*, next page.

ONION THRIPS

Identification: Usually under 2 mm in length, adult thrips have straw-brown bodies and four wings fringed with hairs. Nymphs are smaller, wingless and pale white in colour. Thrips feeding damage appears as longitudinal, silvery rasping on leaf surfaces.

Severe injury may cause reduced yields and increase susceptibility to diseases.

Period of Activity: Thrips favour hot, dry weather conditions. There are several generations per year.

Thresholds: The threshold for dry cooking onions, leeks and Spanish onions is 1 thrips per leaf.

Management Notes: Early detection of thrips is key to successful control. High water volumes help insecticides penetrate into the leaf axils where the majority of onion thrips are found. Also, spray applications made in the evening have provided better control than applications made during the day. See Table 9-58, *Allium Insect Control Recommendations*, next page. Heavy rainfall is effective in knocking thrips off the plant for a short time but management tools may still be required under high pest populations.

ONION MAGGOT

Identification: The onion maggot fly lays eggs around the base of onion plants. Larvae tunnel into the basal plate of the onion, causing the plant to wilt and die. Small onion plants are most susceptible to feeding injury. Crop losses of 50%–70% may occur if in-furrow control measures are not used.

Period of Activity: The onion maggot overwinters as a pupa in the top 15 cm of the soil. The three generations found in Ontario emerge in early June, July and late August. This pest is present in all onion fields in the Bradford, Keswick and Thedford-Grand Bend areas.

Table 9–58. Allium Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ONION MAGGOT						
Soil Treatment (In-Furrow Granular)						
organophosphate (group 1B)	chlorpyrifos	Lorsban 15 G	8–16 kg	3.2–6.5 kg	109	Dry onions only. 24-hr re-entry interval. See the label for spacing and planter specifications.
		Pyrifos 15 G			97	Pickling onions only. 24-hr re-entry interval. See the label for spacing and planter specifications.
Foliar Sprays for Onion Maggot Flies						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	175 mL	71 mL	3	Onions only.
		UP-Cyde 2.5 EC	280 mL	113 mL	3	Onions only. Maximum 3 applications/yr. 12-hr re-entry interval.
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.4 kg	10	Onions only.
		Diazinon 500 E	1.1 L	0.4 L	10	
	naled	Dibrom	550 mL	222 mL	4	Onions only. 48-hr re-entry interval.
THRIPS						
pyrethroid ² (group 3)	lambda-cyhalothrin	Matador 120 EC	188 mL	76 mL	14	Maximum 3 applications/yr. 24-hr re-entry interval.
		Silencer 120 EC	in 500 L water	in 50 gal water		
	cypermethrin	Ripcord 400 EC	175 mL	71 mL	3	Onions only. Maximum 3 applications/yr.
		UP-Cyde 2.5 EC	280 mL	113 mL	3	Apply at 10 day intervals. Maximum 3 applications/yr. 12-hr re-entry interval.
	deltamethrin	Decis 5 EC	200 mL	81 mL	5	Maximum 1 application/yr.
organophosphate (group 1B)	naled	Dibrom	550 mL	222 mL	4	48-hr re-entry interval.
LEEK MOTH						
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	188 mL in 500 L water	76 mL in 50 gal water	14	Maximum 3 applications/yr. 24-hr re-entry interval. 10-day re-entry for hand harvest and thinning of green onions.
CUTWORMS						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	175 mL	71 mL	21	Do not disturb soil for 5 days after treating.
	permethrin	Pounce	180–390 mL	73–158 mL		Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application. Use high rate on large larvae, dry soils or muck soils. 12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC	140–300 mL	57–121 mL		
organophosphate (group 1B)	chlopyrifos	Lorsban 4E	2.4–4.8 L	1–1.9 L	60	Dry onions (bulb and pickling) only. Apply between 2–5-leaf stage. 24-hr re-entry interval.
		Pyrinex 480 EC				

¹ PHI = Pre-Harvest Interval (days).² Resistance to these insecticides has been observed in Ontario muck soils.

Thresholds: First-generation onion maggot thresholds are a combination of trapping and visual scouting. Place four traps (of 3 sticky boards each) centrally along each field edge. Check traps weekly. Assess the percent damage using plots containing 100 onions repeated four times within the field:

Amount of damage	Trap Counts	Action
< 2% damage		Do not spray.
2–5% damage	and 5 flies/trap/day	Spray.
> 5% damage	and 2 flies/trap/day	Spray.

Management Notes: Apply a granular insecticide at seeding or use treated seed. If these treatments work, first-generation damage may be negligible. Seedlings killed by the first generation are often compensated for with more rapid growth in adjacent onions.

Treatments against adult flies of the first and second generation are not recommended on dry, cooking or Spanish onions. Spraying for adult flies does nothing to prevent or reverse onion maggot damage.

See Table 9–58, *Allium Insect Control Recommendations*, this page.

LEEK MOTH

In Central and Eastern Ontario, leek moth damage has been recorded in garlic, leek and onion fields. The larvae tunnel mines and create pinholes in the leaf tissue, occasionally attacking the bulb. For further information, see *Leek Moth*, on page 121, and Table 9-58, *Allium Insect Control Recommendations*, opposite page.

For more information on insect management for onions, see the following OMAFRA Factsheets and publication:

- *Thrips on Onions and Cabbage*, Order No. 99-027
- *Onion Maggot Control*, Order No. 00-017
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*
- *Leek Moth – A Pest of Allium Crops*, Order No. 08-009

Nematode Control

See *Nematodes*, on page 63, for nematode control recommendations. For more information, see the OMAFRA Factsheet *Bulb and Stem Nematode in Onions and Carrots*, Order No. 00-043.

Physiological Disorders**Ozone Injury**

This injury begins as small flecks, which can form into whitish spots. These spots may be confused with botrytis leaf blight or iris yellow spot virus lesions.

Sprout Inhibitor Injury

Maleic hydrazide applied to immature crops can result in spongy bulbs. See *Harvest and Storage*, this page, for more details.

Sunscald

Sunscald causes severe damage to onions curing in the field. Turn onions during curing to avoid injury. Sunscald injury leads to secondary bacterial infections, which can result in severe storage losses.

Harvest and Storage**Dry Bulb Onions (cooking, Spanish and shallots)**

Weather and soil conditions often determine the timing of harvest and quality of dry bulb onions. Signs of maturity are soft neck tissues, fallen-over tops and dead roots. Mature onions have better longevity in storage.

The proper use of maleic hydrazide (Royal MH 60) inhibits sprouting and lengthens the storage life of many onion cultivars. Cultivars with a naturally short storage life do not benefit from maleic hydrazide applications.

The optimum time for spraying is when 50% of the tops have fallen, but tops are still green. This usually occurs 8–14 days before harvest. Plants with less than three green leaves and/or severely diseased foliage will not absorb maleic hydrazide.

Onions are typically cured in the field. Optimum curing occurs in average air temperatures of 24°C–30°C and a relative humidity is at least 60%. In humid areas, or during cool, wet harvest periods, artificial curing can be beneficial. Place pallet boxes into well-ventilated storage facilities and heat to 35°C and 60% relative humidity for 3–4 days.

Storage conditions must be maintained at 0°C and 65%–70% relative humidity with good air circulation. Properly stored cooking onions and shallots can be held for 8 months. Spanish onions may last for 2 months in storage.

Bunching (Green) Onions and Leeks

Harvest green bunching onions and leeks as whole plants. Trim roots off close to the base of the bulbs and remove the older, outer scales.

Store green bunching onions for 3–4 weeks and leeks for 3–6 months. Consistent post-harvest chilling near 0°C and careful post-harvest handling will maximize storage life.

For more information, see these OMAFRA Factsheets and publication:

- *Shallots: What They Are and How to Grow Them*, Order No. 98-037
- Publication 486, *Onions*

PARSNIPS

Production Requirements

Parsnips require deep, loose, fertile, sandy loam soils with a preferred pH of 6.5. Well-drained muck soils with a target pH of 5.5 are also suitable. Parsnips take 100–130 days to mature and should be planted as soon as soil conditions permit in the spring.

In Ontario, some parsnips are lifted in late August and sold fresh. Most of the crop is harvested in October and November for winter storage. A portion of the crop may be left in the ground over the winter and harvested in early spring the following year.

Recommended rotational crops: onions, beets, spinach, cereal crops

Do not rotate with: brassica crops, other umbellifera crops (e.g., celery, parsley)

Average Yield

Crop	per acre	per hectare
Parsnips	400–500 bushels of graded product	1,000–1,250 bu boxes of graded product

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Planting, Seeding and Spacing

The minimum temperature for seed germination is 2°C. Optimum planting conditions occur when soil temperatures reach 10°C–21°C. Planting into cool soil conditions may result in reduced stands due to poor germination, low vigour and increased seed decay.

Poor stands occur in over-worked soil surfaces (e.g., baked or crusted). For more information on how to improve soil structure and prevent crusting, see Chapter 2, *Soil Management*, on page 21.

	Metric	Imperial
Rate:	3–5.5 kg/ha	3–5 lb/acre
Row spacing:	45–75 cm	18–30 in.
In-row spacing:	3–6 cm	1–2.5 in.
Depth: (always plant into moisture)	6–20 mm	<1 in.

Table 9–59. Parsnip Nitrogen Recommendations

Soil Type	Actual N kg/ha
Mineral Soils	
Preplant	70
Side-dress	40
Total	110
Muck Soils	
Preplant	60

Fertility

Fertilizer requirements are the same as for carrots. (See Table 9–59, *Parsnip Nitrogen Recommendations*, this page.)

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, parsnips grown on both mineral and muck soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, parsnips grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Integrated Pest Management Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–60, *Parsnip Disease and Insect Control Recommendations*, opposite page.

PHOMA CANKER AND LEAF SPOT, ITERSONILIA CANKER

Identification: Both diseases cause brown cankers on the crown and root shoulders. Leaf symptoms include small (1-mm) spots with yellow-green halos. Phoma cankers are often embedded with small, black spores.

Table 9–60. Parsnip Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
PYTHIUM DAMPING-OFF						
phenylamides (group 4)	metalaxyl-M	Apron XL LS	20–40 mL/100 kg seed			Seed treatment. For use in commercial seed treatment plants only.
PHOMA CANKER						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.8 L	1.1 L	7	48-hr re-entry interval.
CARROT RUST FLY (ADULTS ONLY)						
organophosphate (group 1B)	diazinon	Diazinon 500 E	1.1 L	0.4 L	10	
		Diazinon 50 W	1.1 kg	0.4 kg	10	

¹ PHI = Pre-Harvest Interval (days).

Development: Phoma canker and leaf spot appear in mid-August. Development is favoured by moderate temperatures, rain and high humidity.

Itersonilia canker requires cool, wet conditions (temperatures around 20°C). The fungus overwinters in infected roots and is spread within the field by spores. Itersonilia can also spread through infested seed.

Thresholds: None have been established.

Management Notes: Harvesting before maximum root and shoulder development can reduce phoma canker development. High ridging to cover the shoulder of the roots throughout the season may minimize itersonilia canker infections. Control of carrot rust fly will help reduce secondary itersonilia infections. Follow a long rotation and bury infected residue. See Table 9–60, *Parsnip Disease and Insect Control Recommendations*, this page.

Insects

CARROT RUST FLY

See *Carrot Rust Fly*, on page 98. If monitoring indicates a need, apply insecticide as directed in Table 9–60, *Parsnip Disease and Insect Control Recommendations*, this page.

Root-Knot Nematode Control

See *Nematodes*, on page 63.

Harvest and Storage

Roots may be kept in cold storage for 4–6 months at 0°C and 98%–100% relative humidity. The sweet, nut-like flavour of parsnips develops after exposure to temperatures near freezing (late September and October). If mature roots are not exposed to low field temperatures, store for 2 weeks at 0°C–1°C to develop flavour. Extremely low temperatures in storage may damage root tissues. Parsnips will freeze at 1.7°C.

Caution

Some individuals may be sensitive to furocoumarins, the natural chemicals found in parsnip foliage. The level of furocoumarins increases in diseased parsnips. Using rubber gloves when handling parsnip foliage and leg protection when walking in the field will prevent the development of skin rashes.

PEAS

Production Requirements

Peas are a hardy, cool-season vegetable crop. Optimum pea growth occurs at temperatures in the range of 10°C–17°C. Crops grown during the warmer part of the summer (temperatures above 24°C) will mature rapidly and develop overly fibrous pods and starchy seeds. Most pea varieties mature in 50–60 days.

Peas are suited to well-drained soils. Avoid planting the early crop into heavy soils or variable fields, as they are more prone to root rots and seed insects. The target soil pH is 6.1–6.5. Consider inoculating the seed with rhizobia if peas have not been grown in a field in the past 5 years.

Recommended rotational crops: corn, cereal crops, brassica crops, cucurbit crops, tomatoes, peppers, root vegetables

Do not rotate with: peas, beans

Average Yields

Type	per acre	per hectare
Processing	2–3 tons	4–7 tonnes
Fresh market	150 bu	375 bu

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under Ontario growing conditions. A list of seed suppliers is available in Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

Seed size varies considerably between varieties. Adjust the planting rate according to both seed size and percent germination. Pea seed requires a minimum soil temperature of 4°C for germination. Planting into colder soils will slow early growth, resulting in uneven stand establishment. Optimum germination occurs at temperatures of 4°C–24°C.

	Metric	Imperial
Row Spacing:	15–20 cm	6–8 in.
In-Row Spacing:	4–5 cm	1½–2 in.
Rate:	100–300 kg/ha	90–270 lb/acre
Depth: (Always plant into moisture.)	2.5–5 cm	1–2 in.

Fertility

Apply and incorporate fertilizer requirements prior to planting. Do not drill fertilizer with the seed.

Nitrogen

Where phosphate and potash are required, apply 15 kg N/ha at seeding. If no phosphate and potash are required, the nitrogen may be omitted.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 16 mg P per L soil (ppm) or higher, peas are unlikely to respond to additional phosphate applications. For soils testing lower than 16 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 121 mg K per L soil (ppm) or higher, peas are unlikely to respond to additional potash applications. For soils testing lower than 121 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Integrated Pest Management Diseases

DAMPING-OFF AND ROOT ROTS

These diseases are the most common cause of yield loss in peas. For information on identification and management, see *Damping-Off and Root Rots* (*Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Penicillium*), on page 59.

Also see Table 9–61, *Pea Seed Treatments*, opposite page.

Table 9-61. Pea Seed Treatments

Active Ingredient(s)	Trade Name	insects		Diseases				Notes
		Seedcorn Maggots	Wireworm	Ascochyta ¹	Pythium	Fusarium	Rhizoctonia	
thiamethoxam/ metalaxyl-M/ fludioxonil	Cruiser Maxx Beans	✓	✓	✓	✓	✓	✓	For use in commercial seed-treatment plants only. See the product labels for rates. Use the high rate for wireworm and broad spectrum seedling disease control.
diazinon/ captan	Agrox B-2	✓			✓	✓	✓	Seed box treatment. Use 80 g/25 kg of seed. Do not use on seed previously treated with an insecticide. Use within 1 month of treatment.
diazinon/ captan	Agrox CD	✓			✓	✓	✓	Seed box treatment. Use on seed previously treated with captan or thiram. Use 50 g/25 kg of seed. Do not use on seed previously treated with an insecticide.
fludioxonil/ metalaxyl-M	Apron Maxx RFC			✓	✓	✓	✓	For use in commercial or on-farm seed-treatment equipment only. Use 100 mL/100 kg of seed.
metalaxyl-M	Apron XL LS			✓	✓		✓	For use in commercial seed-treatment plants only. See the product label for rates.
metalaxyl	Apron FL				✓			For use in commercial seed-treatment plants only. See the product label for rates.
	Allegiance FL				✓			
carbathiin/ thiram	VitaFlo			✓	✓	✓	✓	Snap beans only. For use in commercial seed-treatment plants only. See the product label for rates. Do not store treated seed.
thiram	Thiram 75 WP				✓	✓	✓	Seed box treatment. Use 25–30 g per 25 kg of seed.
thiamethoxam	Cruiser 5 FS	✓	✓					For use in commercial seed-treatment plants only. See product label for rates. Request the high rate for wireworm control. Also controls early-season soybean aphid.

✓ = registered pest

¹ Seed-borne.**ASCOCHYTA (MYCOSPHAERELLA) BLIGHT**

Identification: Infected seedlings develop symptoms similar to damping-off. The stem tissue above the soil-line turns black, reducing water and nutrient uptake. Plants become stunted and weakened.

Infections on established plants cause brown spots on the leaves and stems. The spots have a distinctive dark border. Infected leaves eventually turn yellow and dry off. Plants remain standing and become straw-like.

Development: This disease complex is transmitted through seed-, soil- and wind-borne spores. Spores travel for long distances and can infect large areas. Humid conditions in the crop canopy promote disease development.

Management Notes: Follow a 4–5-year rotation away from peas and other legume crops. Promote vigorous

early-season growth by planting into warm soils and minimizing compaction. See Table 9-62, *Pea Disease and Insect Control Recommendations*, next page.

WHITE MOULD (SCLEROTINIA)

White mould is an occasional problem in processing peas. Infection occurs as a result of warm, wet conditions during flowering. A white, cottony growth develops on the pods. Hard, black sclerotia are often imbedded in the fungi. These sclerotia may be difficult to grade-out during processing.

White mould is a common problem in beans (snap, edible and soy). Follow a 2-year rotation away from all white mould host crops. For more information, see *White Mould (Sclerotinia)*, on page 73, and Table 9-62, *Pea Disease and Insect Control Recommendations*, next page.

Table 9–62. Pea Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes	
MYCOSPHAERELLA AND ASCOCHYTA BLIGHT							
Qol (group 11)	pyraclostrobin	Headline EC	400–600 mL	161–243 mL	7	Maximum 2 applications/yr. 12-hr re-entry interval.	
carboxamide (group 7)	boscalid	Lance WDG	420 g	170 g	7	Maximum 2 applications/yr. 4-hr re-entry interval.	
WHITE MOULD (SCLEROTINIA)							
carboxamide (group 7)	boscalid	Lance WDG	560–770 g	226–312 g	7	Maximum 2 applications/yr. 4-hr re-entry interval.	
APHIDS							
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	83 mL	34 mL	14	May also control lygus bugs. Maximum 3 applications/yr. Do not feed or graze treated vines. 24-hr re-entry interval.	
		Silencer 120 EC	in 200 L water	in 18 gal water			
carbamate (group 1A)	methomyl	Lannate TNG	510 g	206 g	1	24-hr re-entry interval.	
organophosphate (group 1B)	dimethoate	Cygon 480	275–425 mL	111–172 mL	3	Do not feed or graze vines within 21 days of last application. Maximum 2 applications/yr.	
		Lagon 480					
	malathion	Malathion 25 W	4.25 kg	1.7 kg	3		
		Malathion 500 E	2.25 L	0.9 L	3		
chlorinated cyclodiene (group 2A)	endosulfan	naled	Dibrom	1.1–2.2 L	0.4–0.9 L	4	Processing only. 48-hr re-entry interval.
		Thiodan 4EC	1.5–2.0 L	0.6–0.8 L	7	Processing only. Do not feed or graze treated vines. Maximum 2 applications/yr.	
			Thionex 50 WP	1.1–1.75 kg	0.4–0.7 kg		7
SLUGS							
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Use higher rates on severe infestations.	
CUTWORMS							
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	83 mL	34 mL	14	Apply in the late evening or at night. Do not feed or graze treated vines. 24-hr re-entry interval.	
		Silencer 120 EC	in 200 L water	in 18 gal water			
	permethrin	Pounce 384 EC	180–390 mL	73–158 mL		Apply in the late evening or at night. Apply up to 5-leaf stage. Use high rates on dry soils and/or large cutworms. Do not disturb soil for 5 days after treating. 12-hr re-entry interval.	
		Perm-UP					
Ambush 500		140–300 mL	57–121 mL				

¹ PHI = Pre-Harvest Interval (days).**POWDERY MILDEW AND DOWNY MILDEW**

Powdery mildew and downy mildew are also an occasional problem in peas. These diseases overwinter in the southern U.S. and are blown into Ontario annually. Powdery mildew infections may reduce the yield and quality of late crop peas. It develops under a wide range of environmental conditions. Downy mildew infections occur during cool, wet seasons. A dense grey mould develops on the underside of the leaf. Severe infections will cause the plants to turn slimy and fall over.

Insects**SEEDCORN MAGGOTS, WIREWORMS, MILLIPEDES, SLUGS, APHIDS, CUTWORMS**

For identification and management information on these common vegetable insects affecting peas, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

Also see Table 9–61, *Pea Seed Treatments*, previous page, and Table 9–62, *Pea Disease and Insect Control Recommendations*, this page.

Harvest and Storage

Remove the field heat from peas immediately after harvest. Store at 0°C and 95%–98% relative humidity. Under ideal conditions, fresh-market peas will store for 1–2 weeks.

Early harvested peas are an ideal opportunity to include a cover crop in your rotation. Not only do cover crops protect the soil from wind and water erosion, they also scavenge residual nitrogen from the soil and add organic matter back into the soil. For more information on cover crops, see Chapter 2, *Soil Management*, on page 21.

PEPPERS

Production Requirements

Peppers grow well in a wide variety of well-drained mineral soils. Lighter soils produce earlier crops. Peppers perform best at a pH of 6.0–6.8. Cultivars grown in Ontario take from 60–76 days to progress from transplanting to mature green fruit. Full-size green fruit are ready to harvest approximately 30–40 days after pollination. Add 20–25 days for ripe colour to develop.

Recommended rotational crops: beans, brassica crops, cereal crops, corn, peas, soybeans

Do not rotate with: eggplant, potatoes, tomatoes, cucurbit crops

Average Yields

Type	per acre	per hectare
Processing	10–12 tons	22–27 tonnes
Fresh market	6–8 tons	13–18 tonnes

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. Processors will determine variety selection for crops produced under a processing contract. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

Plant 200 g of seed to get enough transplants for 1 ha. For more information, see *Transplanting*, on page 39.

	Row Spacing	In-Row Spacing	Bed Centres
Single rows:			
Early varieties	1.0 m (3 ft)	30 cm (12 in.)	
Standard varieties	1.0 m (3 ft)	45 cm (18 in.)	
Twin rows:	45 cm (18 in.)	45 cm (18 in.)	1.5 m (5 ft)

Plasticulture

Peppers respond well to plastic mulch, row covers and drip irrigation. However, keep in mind that peppers are very sensitive to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature inside the row cover regularly and ventilate when it reaches 35°C or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. For more information, see *Season Extension*, on page 34.

Fertility

Nitrogen

Reduce the nitrogen (N) application if manure is applied or legume sod is plowed down. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Broadcast and incorporate the recommended preplant nitrogen, along with the required phosphate and potash, prior to planting. Side-dress the remainder of the nitrogen after first fruit set.

For fertigated peppers, broadcast and incorporate the recommended preplant nitrogen, along with all the required phosphate and half the required potash. Apply equal rates of nitrogen and potash through the drip tape according to the schedule in Table 9–63, *Pepper Nitrogen Application Schedule*, this page. For more information, see *Fertigation*, on page 30.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, peppers are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Starter Solution

At transplanting, apply a high-phosphorus starter solution. Starter fertilizer is especially important when planting in cool soils. Starter fertilizers are available in several forms, including liquids (e.g., 10-34-0 or 6-24-6), soluble or granular materials (e.g., 10-30-20 or 10-52-10). Apply according to the recommendations in Table 9–64, *Transplant Starter Solution Recommendations*, next page.

Table 9–63. Pepper Nitrogen Application Schedule

Method	Actual N/ha
Soil-applied	
Preplant	35 kg
Side-dressed	35 kg
Total	70 kg
Fertigated	
Preplant (broadcast)	35 kg
Transplanting to fruit set	3–5 kg/week
Fruit sizing	7–10 kg/week
Harvest	3–5 kg/week

Table 9–64. Transplant Starter Solution Recommendations

Soil Temperature	Starter Concentration ¹
less than 18°C	Use full label rate as recommended.
18°C–27°C	Use half of recommended rate.
greater than 27°C	Starter not normally required.

¹ Under dry conditions or in sandy soils with less than 2% organic matter, use half the recommended rates.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, peppers are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

For more information on integrated pest management in peppers, see the OMAFRA Publication, *Ontario CropIPM*, Order No. AF141.

Transplant Production — Disease and Insect Management

Bacterial spot is a serious disease of peppers. Talk to your seed supplier to ensure that proper seed disinfectant treatments have been used. A greenhouse spray program with a fixed copper fungicide can help reduce the rate of disease development. Apply every 5 days, starting 2½ weeks after seeding. Use low water volumes — wet the foliage, but not to excessive runoff. Ensure foliage is dry when shipping plants.

Fungicides and insecticides registered for greenhouse transplant production are listed in Table 9–65, *Greenhouse Pepper Transplant Disease and Insect Control Recommendations*, opposite page. For more information on vegetable transplant production, see Chapter 5, *Seeding and Transplanting*, on page 37.

Duponchelia fovealis is a moth that has recently been found in some Ontario greenhouses. It has a broad host range that includes vegetables. The larvae feeds on host plants. The presence of the pest can lead to trade restrictions for crops being exported to the U.S. Any suspected findings of *Duponchelia fovealis* must be reported to the CFIA. The pest does not survive winters outside of the greenhouse.

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

To prevent damping-off, use sterile, soil-less mix for growing seedlings. Fungicides registered for greenhouse transplant production are listed in Table 9–65, *Greenhouse Pepper Transplant Disease and Insect Control Recommendations*, opposite page. Also see Chapter 5, *Seeding and Transplanting*, on page 37.

ANTHRACNOSE, BOTRYTIS & ALTERNARIA

Anthracnose infects immature and mature fruit. Disease development is greatest during warm, wet weather. Fruit lesions appear as small, sunken, water-soaked, circular spots. The lesions gradually expand and darken in the centre.

Botrytis and *Alternaria* are not important pathogens of field pepper, and generally only infect fruit that have been wounded or damaged (i.e., by blossom-end rot or sunscald). *Botrytis* is more common in prolonged wet conditions. *Botrytis* occasionally attacks pepper seedlings.

See Table 9–66, *Pepper Disease Control Recommendations*, on page 152.

POWDERY MILDEW

Powdery mildew of peppers develops over a wide range of temperatures in low or high humidity conditions. The disease produces a brownish, powdery growth on the underside of the leaves. The upper leaf surface may develop yellow patches; in severe cases, the leaf turns completely yellow and drops off. Symptoms appear on older leaves first.

The pathogen has a wide host range, which includes tomato, however it has not been found to infect tomato in our growing region. Powdery mildew infecting tomato in the northeast U.S. and Ontario has been caused by a different organism; yet another organism causes powdery mildew of cucurbits.

See Table 9–66, *Pepper Disease Control Recommendations*, on page 152.

BACTERIAL SPOT

Identification: Leaf lesions start as small, water-soaked spots that become large, irregular lesions with pale centres and dark edges. The centre of the spots may drop out, giving leaves a "shot-hole" or ragged appearance. If the disease is severe, leaves may turn yellow and drop. Fruit lesions start as green, circular, slightly raised spots, later becoming brown and scabby.

Table 9-65. Greenhouse Pepper Transplant Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	Notes
DAMPING-OFF, ROOT ROT					
phenylamide (group 4)	metalaxyl-M	Apron XL-LS		20–40 mL/ 100 kg of seed	Seed treatment. Pythium damping-off. For import use only.
carbamate (group M3)	thiram	Thiram 75 WP		90 g/ 25 kg of seed	Seedbox treatment.
pthalamide (group M3)	captan	Maestro 80 DF		1.25 kg/ 1,000 L of water	Soil drench treatment. 48-hr re-entry interval.
		Supra Captan 80 WDG		Apply 50–85 L of solution per 100 m ² (1,076 ft ²)	
dithiocarbamate (group M2)	oxine benzoate	No-Damp		10 mL/ L of water	Soil treatment.
PHYTOPHTHORA BLIGHT					
carboxylic acid amides (group 40)	mandipropamid	Revus	600 mL	243 mL	Suppression only. Make one application as a drench, immediately before transplanting. 12-hr re-entry interval.
BACTERIAL DISEASE					
inorganic (group M1)	copper hydroxide	Kocide 2000	3.2 kg	1.3 kg	Apply every 5 days, when warranted, to a maximum of 5 applications over a 4-week period prior to transplanting. Apply in low water volumes. 24-hr re-entry interval.
DUPONCHELIA FOVEALIS					
biological (group 11)	<i>Bacillus thuringiensis</i>	Bioprotec 3P		800 g/ 1,000 L of water	Apply the product such that it flows along the stem, coating it well, and into the top layer of the soil around the base of the plant. Thorough coverage of foliage and stems is necessary.

Development: Bacterial spot prefers temperatures of 24°C–30°C. Abundant rainfall and high humidity aid infection.

Thresholds: None have been established.

Management Notes: Use disease-free or disinfected seed. Do not plant diseased or unhealthy transplants. Avoid working in fields when foliage is wet. Overhead irrigation may spread this disease. If possible, time irrigation activities early in the day, allowing ample drying time for the foliage. Alternatively, install drip irrigation, which does not wet the foliage.

Some varieties have tolerance to bacterial spot races 1, 2 and 3. Copper fungicides may slow bacterial spot development; see *Bacterial Disease Control With Copper Fungicides*, on page 208, for copper use guidelines.

See also Table 9-65, *Greenhouse Pepper Transplant Disease and Insect Control Recommendations*, this page, and Table 9-66, *Pepper Disease Control Recommendations*, next page.

For more information, see the OMAFRA Factsheet, *Bacterial Diseases of Tomato: Bacterial Spot, Bacterial Speck, Bacterial Canker*, Order No. 05-069.

VERTICILLIUM WILT

Identification: In peppers, verticillium wilt typically begins with wilting. If severe, leaf yellowing occurs, starting with the older leaves. Eventually, necrotic areas develop, starting at the leaf tips and edges, progressing to leaf drop. Split the plant stem at the base to check for discolouration of vascular tissue.

Development: Verticillium is a soil-borne disease. Symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes may further aggravate verticillium wilt.

Thresholds: Soil *Verticillium*, root knot and root lesion nematode counts, available from the Pest Diagnostic Clinic, University of Guelph, will help determine the need for control measures. See Appendix G, *Diagnostic Services*, on page 240.

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with related (solanaceous) crops, strawberries or raspberries. Keep fields clean of host weeds such as nightshades. Cultivars vary in tolerance to verticillium wilt. Soil fumigation may be required if verticillium and nematode counts are high. See *Nematodes*, on page 63.

Table 9–66. Pepper Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
BACTERIAL LEAF SPOT						
inorganic (group M1)	copper hydroxide	Parasol Flowable	2.3–3.12 L	0.9–1.26 L	1	Apply at 7–14-day intervals.
		Kocide 2000	2.52–3.2 kg	1–1.3 kg	1	Apply at 7–10-day intervals. 24-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	4–15 kg	1.6–6.1 kg	0	Suppression only. Begin applications soon after transplant. Repeat as necessary on a 7–10 day interval. When conditions are conducive to rapid disease development, use in a rotational program with other bactericides.
FUNGAL DISEASES						
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	227–340 g	0	Anthracnose and alternaria control. Maximum 6 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 12-hr re-entry interval.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	71–127 g	0	Botrytis grey mould and alternaria. Use 420 g/ha (170 g/acre) to control botrytis grey mould. Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	8–15 kg	3.2–6.1 kg	0	Early blight — suppression only. Also suppresses powdery mildew and grey mould. Make first application when conditions are conducive for disease development. Repeat at 5–7-day intervals.
inorganic salt	potassium bicarbonate	MilStop	2.8–5.6 kg	1.1–2.3 kg	0	Powdery mildew. Spray at 7-day intervals in 1,000 L/ha (10 gal/acre) of water. Use higher rates for heavier disease pressure. 4-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).**VIRUSES (CUCUMBER MOSAIC VIRUS, TOMATO SPOTTED WILT VIRUS, ETC.)**

Identification: Symptoms vary between viruses, cultivars and conditions. Interaction between viruses may occur, complicating visual diagnosis.

Development: Cucumber mosaic is spread by aphids. Thrips are a vector for tomato spotted wilt. The presence of these diseases usually follows periods of high aphid/thrips activity. Tomato mosaic virus is spread mechanically.

Management Notes: Control weed hosts such as pigweeds, nightshades and related weeds, milkweed, purslane and chickweed in and around the field. Spraying for aphids is not effective in controlling the common pepper viruses in Ontario. Tomato spotted wilt virus is rarely of economic concern. See also *Aphids*, on page 60.

Insects**CUTWORMS, TARNISHED PLANT BUG, WIREWORMS, APHIDS**

For identification and management information on these common vegetable insects affecting peppers, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–67, *Pepper Insect Control Recommendations*, opposite page.

EUROPEAN CORN BORER

Identification: Larvae are greasy-looking, grey-to-tan-coloured, with small brown spots on each segment and a dark head. Full-grown borer larvae reach 2.5 cm in length. Adult moths are light brown with wavy lines across the wings. Larvae usually enter the fruit under the cap, leaving an entry hole with sawdust-like frass.

Period of Activity: Corn borers are present from mid-July through September. The second generation, and sometimes a partial third generation, attacks peppers. Peppers become susceptible to feeding when the fruit are the size of walnuts (3 cm in diameter).

Thresholds: There is no tolerance for this pest in processing or fresh-market pepper crops. Use pheromone traps to monitor adult flight activity. Fields can also be scouted for egg masses and feeding activity, but damage is easy to miss.

Management Notes: Protect pepper fruit from fruit set until harvest if corn borers are active in the field. For effective chemical control, excellent spray coverage is essential. See Table 9–67, *Pepper Insect Control Recommendations*, opposite page.

For more information, see the OMAFRA Factsheet, *European Corn Borer in Sweet Corn and Other Horticultural Crops*, Order No. 97-019.

Table 9-67. Pepper Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
APHIDS AND PEPPER MAGGOT						
tetronic and tetramic acid derivatives (group 23)	spirotetramat	Movento 240 SC	220–365 mL	89–148 mL	1	Aphids only. Most effective on young stages. Has slow activity; control may not be apparent for 2–3 weeks. 12-hr re-entry interval.
neonicotinoid (group 4)	thiamethoxam	Actara 25 WG	105 g	42 g	1	Do not apply a foliar neonicotinoid in the same season as a soil application. Alternate applications with other insecticide groups. 12-hr re-entry interval.
	acetamiprid	Assail 70 WP	56–86 g	23–35 g	7	Aphids only. Do not apply a foliar neonicotinoid in the same season as a soil application. Alternate applications with other insecticide groups. 12-hr re-entry interval.
organophosphate (group 1B)	dimethoate	Cygon 480	0.7–1.0 L	0.3–0.4 L	7	
		Lagon 480			3	
	diazinon ²	Diazinon 50 W	0.5–1.0 kg	0.2–0.4 kg	5	Aphids only.
	acephate	Orthene 75 SP	562 g	227 g	7	Maximum 4 applications/yr. 1 day re-entry interval.
	malathion	Malathion 500 E	1.25–2.75 L	0.5–1.1 L	3	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–2.25 kg	0.4–0.9 kg	2	
		Thiodan 4 EC	1.5–2.75 L	0.6–1.1 L	2	
		Thionex 50 WP	1.1 kg	0.44 kg	2	
EUROPEAN CORN BORER						
pyrethroid (group 3)	deltamethrin	Decis 5 EC	250–300 mL	101–121 mL	3	Maximum 3 applications/yr.
	permethrin	Pounce 384 EC	180 mL	73 mL	1	12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC	140 mL	57 mL		
organophosphate (group 1B)	carbaryl	Sevin XLR	2.5–5.25 L	1.0–2.1 L	2	In areas where corn borer has been a problem, spray every 4 days.
	acephate	Orthene 75 SP	825 g	334 g	7	Do not use more than 4 applications/yr. 1 day re-entry interval.
spinosyn (group 5)	spinosad	Success 480 SC	83 mL	34 mL	1	Use only on small larvae and low infestations. Maximum 2 applications/yr.
		Entrust 80 W	50 g	20 g	1	Maximum 2 applications/yr. Time application to target egg hatch or very small larvae. Maintain a spray water pH of 6 or greater.
CUTWORMS						
pyrethroid (group 3)	permethrin	Pounce 384 EC	180–390 mL	73–158 mL	1	Apply in the late evening or at night. Do not disturb soil for 5 days after treating. Use high rates on dry or muck soils or on large larvae. 12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC	140–300 mL	57–121 mL		
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1 L	40	24-hr re-entry interval.
		Pyrinex 480 EC				
MITES						
tetronic and tetramic acid derivatives (group 23)	spiromesifen	Oberon Flowable	500–600 mL	202–243 mL	7	Maximum 3 applications/yr. Apply before mite populations begin to build up. Control may not be apparent for 2–3 wks, especially under cool temperatures. 12-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).² Control of aphids with diazinon has been inconsistent in many areas.

PEPPER MAGGOT

Identification: Larvae are legless, whitish-coloured and approximately 11–12 mm long. They do not have a distinct head. The amber-coloured adult flies have yellow and black markings. Females lay eggs in small fruit, creating a small dimple as the fruit sizes. Larvae feed inside the fruit. They are difficult to detect during scouting and grading.

Period of Activity: Pepper maggot activity is confined to the extreme southwest of Ontario and is of concern only in some years.

Thresholds: There is no tolerance for this pest in processing or fresh-market peppers. Monitor for adults using yellow sticky traps with ammonia lures hung in nearby trees. Visual assessments and sweep nets are also used to monitor adult populations.

Management Notes: If monitoring indicates a need, apply four sprays at 7-day intervals, starting the last week of June or first week of July. See Table 9–67, *Pepper Insect Control Recommendations*, previous page.

Nematode Control

See *Nematodes*, on page 63.

Physiological Disorders**Blossom Drop**

Pepper flowers or small fruit may abort and fall off, due to stressful growing conditions, including:

- daytime temperatures above 30°C–32°C or below 15°C
- nighttime temperatures above 21°C
- dry weather
- excessive nitrogen
- tarnished plant bug injury

Specific varieties may be more sensitive to these stressful growing conditions.

Blossom-End Rot

In peppers, blossom-end rot may occur on the side of the fruit as well as at the blossom-end. See *Blossom-End Rot (BER)*, on page 213, for details on the causes and management of blossom-end rot.

Harvest and Storage

Harvest green peppers when the fruits are large and firm with a glossy skin. Coloured peppers can be harvested once full, ripe colour has developed. After harvest, wash fresh-market peppers in chlorinated water (100–150 ppm chlorine) to eliminate fruit rotting organisms. Green peppers can be held for 2–3 weeks at 7°C–13°C at a relative humidity of 90%–95%. Fully ripe peppers have a shorter storage life.

See *Cooling and Storage*, on page 47.

POTATOES

POTATOES

Production Requirements

Potatoes are adapted to a wide range of soil conditions. The ideal potato soil is a deep, friable, well-drained, sandy loam, free from stones, pH of 6–7, containing adequate organic matter. Such a soil warms up quickly in the spring, holds water well and provides good aeration for the development of tubers. Because potatoes have shallow roots, a minimum of 2.5 cm of water per week is necessary to obtain good yield and quality. Sunny days and temperatures of 18°C–22°C are optimum for vine growth and tuber development.

Cultivars

Table 9–69, *Potato Cultivar Descriptions*, next page, outlines the key characteristics of many potato varieties commonly grown in Ontario. Full variety descriptions are available at the Canadian Food Inspection Agency website: www.inspection.gc.ca/english/plaveg/potpom/var/indexe.shtml. For information on Ontario variety trials, contact the OMAFRA potato specialist.

Recommended rotational crops: cereal crops (especially rye), corn

Do not rotate with: tomatoes, peppers, soybeans

The availability of seed for new or specialty cultivars can often be limited. To ensure a supply of seed, contract with your seed growers. For information on contracting and seed availability lists, contact the Ontario Seed Potato Growers Association at 8193 Main St. W., Everett, ON L0M 1A0, Tel: 705-435-5764.

Seed potatoes fall into seed classes, as shown in Table 9–68, *Canadian Seed Potato Classes*, this page.

Seeding Rate, Spacing and Depth

Row spacing is usually set at 90 cm. Seed potatoes are planted near ground level and covered with 5–8 cm of soil by the planter.

A healthy 55-g seed piece will establish a vigorous plant. Plants from seed pieces smaller than 40 g are generally slower to emerge and have less vigour. Small seed pieces are also more likely to decay before the plant becomes established. Seed pieces cut larger than 55 g result in higher seed costs with little additional benefit.

In-row spacing is based on variety characteristics such as tuber set, resistance to hollow heart and resistance to the development of off-shaped tubers. Wider spacing

Class	Field Generation ¹
Nuclear	Greenhouse Laboratory
Pre Elite	1
Elite I	2
Elite II	3
Elite III	4
Elite IV	5
Foundation	6
Certified	7

¹ Seed drops a class each year in the field if it passes inspection.

(30–32 cm) is recommended for varieties with heavy tuber set, smooth tubers, resistance to hollow heart and low numbers of off-shaped tubers. Closer spacing (20–25 cm) is recommended for varieties with lower tuber set to reduce the number of oversized tubers.

Stand Establishment

Several physiological factors influence stand establishment.

Apical Dominance: Chemical processes within the tuber control the buds in the eyes so that the apical buds will normally be the first to sprout. This process is called apical dominance. The eye at the apical end of the tuber may inhibit other eyes from sprouting. The delay in emergence from non-apical buds will produce uneven stands when using cut seed from varieties with strong apical dominance such as Jemseg and Yukon Gold. Varieties with weak apical dominance, such as Superior, produce more uniform stands from cut seed.

Physiological Age of Seed: Potato seed is not all the same age at harvest. Growing conditions from tuber initiation onwards determine the physiological age of potato tubers. Crop stress during the growing season has an impact on physiological age. Seed grown during a season that was hot and/or dry will be physiologically older at harvest than tubers grown under more favourable growing conditions. Storage temperatures affect physiological age: storage temperatures above 50°C will speed the aging process of the tubers.

Seed tubers can be classified by their physiological age:

Young seed has strong apical dominance. It produces 1–2 sprouts that emerge slowly from the bud, or apical, end of the seed tuber. Low stem number leads to a low tuber set and a harvest of fewer, larger tubers. Young seed has an extended bulking period. This is an advantage with late-maturing varieties.

Table 9–69. Potato Cultivar Descriptions

Cultivar	Maturity	Tuber Type	Scab Tolerance	Comments
Tablestock: White Flesh				
Jemseg	very early	smooth, blocky	MR	Tubers oversize quickly. Susceptible to hollow heart. Susceptible to leaf roll and verticillium wilt. Immune to Virus X. Resistant to Virus Y and S.
Eramosa	very early	round-elongated, flattish	MS	Moderately susceptible to Virus Y. Prone to silver scurf in storage.
Envol	very early	smooth	VS	Lower yielding than Superior. Matures about 7 days earlier than Superior.
Superior	early	smooth	T	Susceptible to verticillium wilt and nematodes. Stress substantially reduces yields.
Onaway	early	rough, white skin	MT	Susceptible to blackleg, verticillium wilt, leaf roll and fusarium dry rot.
Dakota Pearl	medium-early	smooth white skin	T	Sets high, performs better in heavier soils. Susceptible to blackleg. Dual purpose, produces good quality potato chips.
Sifra	Late	smooth, white skin	S	Sets high, attractive tubers. High yield.
Tablestock: Yellow Flesh				
Adora	early	oblong, light yellow, smooth skin	VS	Low dry matter content. Matures about 1 week later than Superior.
Ambra	early	oval, light yellow, smooth skin	S	Sets low, attractive tubers. No culls. Matures 1 week earlier than Superior.
Yukon Gold	mid-season	round to elongated, pink eyes, smooth	VS	Emerges slowly. Use close plant spacings to avoid oversizing and hollow heart. Drought tolerant. Susceptible to air pollution.
Fabula	mid-season	uniform, large, plump, oval	T	Resistant to hollow heart. No culls. Requires low nitrogen.
Vivaldi	late	oval, smooth skin	S	High yield, no culls, even set, no off-shaped tubers.
Tablestock: Cream-Coloured Flesh				
Argos	late	oval, smooth skin, superficial eyes	MT	Tolerates low soil moisture. Do not apply excessive rates of nitrogen.
Tablestock: Red Skin				
Norland	early	smooth, oblong, slightly flattened; shallow eyes	T	Very susceptible to air pollution and moisture stress. Tubers are very susceptible to growth cracks when crop is under sudden stress. Do not use the herbicide metribuzin post-emergence.
Chieftain	late	smooth, round; very white flesh	MR	High yielding. Susceptible to heat necrosis, verticillium wilt, blackleg, Virus X and Y. The red skin tends to fade or scurf-over in some soils.
NorDonna	late	round with shallow eyes	MT	Holds colour well in storage. Susceptible to verticillium wilt. Susceptible to most common viruses.
Dual Purpose: Pre-Peel and Tablestock				
Shepody	mid-late	large, oblong, smooth; white flesh	VS	Do not use the herbicide metribuzin post-emergence. Susceptible to verticillium wilt. Does not perform well in Southwestern Ontario. Susceptible to Virus Y and S.
CalWhite	mid-late	oblong, large with buff-coloured skin and very white flesh	VS	Very vigorous vine and thick stems. Use close plant spacings to avoid oversizing and hollow heart. Susceptible to leaf roll and net necrosis. Sensitive to metribuzin.
Goldrush	late	smooth golden-russet skin, white flesh	T	Very susceptible to early blight. Very susceptible to most viruses. Resistant to hollow heart.
Kennebec	late	elliptical to oblong; smooth, creamy buff skin; thin-skinned	S	Avoid excess nitrogen. Use close plant spacings to avoid oversizing. Tubers are very susceptible to greening. Very susceptible to verticillium wilt and pink eye. Resistant to Virus A and Y.
Gourmet or Specialty Market				
All Blue	mid-late	blue skin and flesh	S	Prone to silver scurf.
German Butterball	mid-late	oval with dark yellow flesh	S	High yield. Excellent flavour.
Banana	late	long, thin fingerling; yellow skin and flesh	S	Produces 12–15 tubers per plant. Excellent flavour.
Scab tolerance: VS = Very Susceptible MS = Moderately Susceptible S = Susceptible MT = Moderately Tolerant T = Tolerant MR = Moderately Resistant R = Resistant				

Middle-age seed emerges faster than young seed; multiple sprouts are produced because there is no clear apical dominance. The multiple stems lead to higher tuber set and higher yields.

Old seed produces branched sprouts. It does not have clear apical dominance. Typically, plants from old seed will produce high tuber sets but the plants lack the vigor to bulk the tubers to a desirable size.

Eye Distribution: Eye distribution on seed tubers is important. Some varieties have even eye distribution (Superior) while others have eyes concentrated at the apical end. When cut by machine, the latter varieties produce a large proportion of blind seed pieces. Large tubers accentuate the problem and should be graded out and cut by hand.

Check seed coming off the cutter frequently for size, blind pieces and slivers.

Seed Handling and Management

Plant Elite or Foundation Class seed to reduce leaf-roll, mosaic and bacterial diseases. Inspect seed on arrival for heating, freezing, grade and visual signs of tuber disease. Seed lots can be regraded by a local Agriculture and Agri-Food Canada seed potato inspector. Requests for reinspection must be made within two working days of the receipt of the seed potatoes.

Request at least two certification tags with each bulk load — one for your bin and one for your files. The tag number provides direct access to the seed grower. Handle, store and plant the seed carefully. Poor stands and field performance are not always the seed grower's fault.

To help prevent disease, discard all tubers and seed pieces showing signs of rot. Follow good sanitation practices in storage areas and on all knives, containers and handling equipment. See *Storage Sanitation*, on page 50.

Pad all seed-handling equipment as you would harvest equipment. Reduce drops to less than 15 cm to minimize bruising. Ensure that cutter knives are sharp. Cold storage temperatures make seed tubers more sensitive to bruising. Warm seed to at least 5°C–10°C prior to handling. Bruising acts as an entry site for pathogens leading to seed piece decay. Mishandling may physiologically age seed, leading to more stems per plant, smaller tubers and more stress susceptibility.

Cut seed not being planted immediately should be given special attention to ensure healing and suberization by:

- forced-air circulation through the shallow pile
- temperatures of 10°C–15°C
- high relative humidity of 90%–95% (prevent free water from forming on tuber surfaces)

Maintain these conditions for 3–4 days. After this, temperature may be lowered, but humidity must be maintained and fans run intermittently.

Never allow cut seed to stand in the hot sun or in drying wind. This causes minute cracks in the skin that allow bacteria and fungi to establish. Do not plant seed tubers that have been washed.

Seed Piece Treatments

Serious problems with seed piece decay are often related to adverse weather during the planting season. Fungal seed piece decay is usually caused by several species of the fungus *Fusarium*. These pathogens need wounds to enter the seed piece.

There may be little benefit from seed piece treatments if soil conditions are optimal during planting and crop emergence. However, if unfavourable environmental conditions develop soon after planting, treated seed usually produces a better stand. Seed treatments may also help in managing other diseases, including rhizoctonia canker, late blight and blackleg.

Mancozeb, the active ingredient of some *Fusarium* seed treatments, also protects healthy seed pieces against late blight. The late blight fungus can produce spores on cut surfaces of infected tubers in 24 hours. These spores will infect healthy seed pieces. Seed treatments that do not contain mancozeb, such as Maxim and Senator, do not protect healthy seed against late blight infection. Mancozeb does not cure existing late blight infections; it only prevents new infections.

Gypsum-based coatings act as a drying agent but have no insecticidal or fungicidal activity. Seed treatments are usually dusted onto cut seed as it moves along the conveyor. The seed may then be moved through a rotating drum apparatus to distribute the treatment more evenly. Check the applicator often to be certain that the treatment is being applied at the labelled rate.

See Table 9–70, *Potato Seed Piece Treatment Recommendations*, next page.

Do not plant seed lots known to be infected with late blight.

Table 9–70. Potato Seed Piece Treatment Recommendations

Group	Common Name	Trade Name	Rate/100 kg seed	Diseases or Insects Controlled
benzimidazole	thiophanate-methyl	Senator PSPT	500 g	Fusarium dry rot, and seed-borne verticillium.
dithiocarbamate	metiram	Polyram 16 D	450–650 g	Fusarium dry rot.
	mancozeb	Tuberseal	500 g	Fusarium dry rot.
phenylpyrrole	fludioxonil	Maxim PSP ¹	500 g	Fusarium dry rot and seed-borne rhizoctonia.
		Maxim Liquid PSP ¹	5.2 mL	Fusarium dry rot and seed-borne rhizoctonia.
phenylpyrrole/ dithiocarbamate	fludioxonil/ mancozeb	Maxim MZ PSP ¹	500 g	Fusarium dry rot and seed-borne rhizoctonia.
neonicotinoid ² (group 4)	imidacloprid	Admire SPT	26–39 mL	Colorado potato beetle, potato flea beetle, potato leafhopper, aphids.²
		Alias 240 EC		
		Grapple		
	thiamethoxam	Actara 240 SC	24.4 mL	Colorado potato beetle, potato leafhoppers, aphids.² Maximum rate cannot exceed 488 mL/ha or 195 mL/acre.
	clothianidin	Titan ST	20.8 mL	Suppression of wireworms only. Maximum 1 application/yr. Do not dilute with any more than 6 parts water to 1 part Titan ST insecticide. Plant seed pieces as soon as possible after cutting and treating.
Growth Regulator				
carboxylic acid	giberellic acid	Falgro Tablet	1 tablet in 75 L of water (treats 61,000 kg seed)	For increased tuber set and smaller tuber profile for seed, table and processing potatoes.

¹ Maxim treatments may increase the number of stems, leading to smaller tuber size.² Do not apply a foliar neonicotinoid spray in fields where a neonicotinoid was used either in-furrow or as a seed treatment.

Chitting or Green Sprouting

This process may be used for limited plantings, where early emergence and yield are important, or in short-season areas. Chitting is the process of aging seed in the light to control sprout growth, resulting in earlier emergence and sizing. Chitting will take several weeks, so plan well ahead of the expected planting date.

Small, whole seed is placed in shallow containers, 2–3 tubers deep. Air movement and light penetration are essential. Seed can be chitted in a building with fluorescent lights or by natural light in a greenhouse. Short, stubby, dark-green sprouts are desirable to minimize sprout damage at planting.

Chitting seed in cool temperatures (such as 8°C) under fluorescent light results in shorter sprouts than using warmer temperatures. Seed taken from winter storage of 3°C–4°C will require about 250 degree-days (base 4°C). For the degree day (DD) calculation, see *Growing Degree Days*, on page 32.

If the daily maximum temperature is 15°C and the daily minimum temperature is 5°C, using the 4°C base, it would take approximately 41 days ($250 \text{ DD} \div 6$) to green-sprout the tubers.

Plant green-sprouted tubers with cup or bell planters to reduce the chances of injuring the sprouts. Avoid

pick planters. Sized seed will improve the uniformity of emergence.

If a greenhouse is unavailable, seed can be chitted at 20°C in natural shaded light for about 2 weeks with similar results. The same can be accomplished inside a heated building. Higher levels of fluorescent light are required than at cool temperatures. In all cases, relative humidity should be approximately 80% to prevent dessication and premature rooting.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

See Table 9–71, *Potato Nitrogen Recommendations*, opposite page. If the total nitrogen-plus-potash applied is over 360 kg/ha, broadcast at least a portion before planting to avoid concentrating the fertilizer band near the seed piece and potato roots. Broadcasting or side-dressing nitrogen after potatoes are 20 cm high is not generally recommended, as it may delay maturity.

Table 9-71. Potato Nitrogen Recommendations

Soil	Actual N kg/ha	Expected Marketable Yield t/ha
Mineral main crop	50	15
	75	20
	130	25
	200	30+
Mineral early crop	70	—
Muck early and main crop	up to 60	—

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 51 mg P per L soil (ppm) or higher on mineral soils, phosphate applications may be reduced to 30 kg/ha. For soils testing lower than 51 mg P per L soil (ppm), see Table 1-10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

On muck soils with soil test P values of 61 mg P per L soil, potatoes are unlikely to respond to additional phosphorous applications. For muck soils testing lower than 61 mg P per L soil (ppm), see Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

On mineral soils testing medium or low for phosphate, place some or all of the phosphate fertilizer in bands 2.5 cm below and 6 cm to each side of the seed piece at planting time. On muck soils or on mineral soils testing high for phosphate, placement is less critical and fertilizer may be broadcast.

Potassium

Soil tests are required to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, potatoes are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1-11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1-12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Many of the sandy loam soils commonly used in potato production are especially prone to organic matter degradation, wind and water erosion. For information on how to maintain and improve soil quality, see Chapter 2, *Soil Management*, on page 21.

Table 9-72. Potato — Interpretation of Plant Analysis

Values apply to the fourth leaf, including stem, from the growing tip sampled at early bloom.

Nutrient	Units	Critical Concentration ¹	Maximum Normal Concentration ²
Nitrogen	%	2.50	3.50
Phosphorus	%	0.15	0.50
Potassium	%	1.20	2.50
Calcium	%	1.50	—
Magnesium	%	0.10	0.60
Sulphur	%	0.14	—
Boron	ppm (µg/g)	2.0	25.0
Copper	ppm	2.0	25.0
Manganese	ppm	15.0	150.0
Zinc	ppm	14.0	70.0

¹ Yield loss due to nutrient deficiency is expected with nutrient concentrations at or below the "critical" concentration.

² Maximum normal concentrations are more than adequate but do not necessarily cause toxicities.

Petiole/Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information, see *Plant Tissue Analysis*, on page 3.

Only use sufficiency ranges as a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. Samples for plant analysis should be taken, in the morning, at early bloom. Sample at least 50 plants distributed throughout the chosen area. Take the fourth leaf from the tip, including the petiole. Sample problem areas separately. See Table 9-72, *Potato — Interpretation of Plant Analysis*, this page.

Integrated Pest Management**Diseases**

Practice a suitable crop rotation to prevent build-up in the soil of organisms causing verticillium wilt, *Rhizoctonia* diseases, common scab and early blight. Follow a broadspectrum protectant fungicide program, starting no later than row closure. See Table 9-73, *Potato — Broad Spectrum Protectant Fungicide Recommendations*, next page.

SEED-PIECE DECAY

See *Seed Handling and Management*, on page 157. Seed piece treatments will not control bacteria.

Table 9-73. Potato — Broad Spectrum Protectant Fungicide Recommendations

Start spraying prior to row closure.

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
chloronitrile (group M5)	chlorothalonil	Bravo 500	1.2–2.4 L	0.5–1.0 L	1	Use high rate under severe disease pressure. Use higher rates as the crop canopy closes. 48-hr re-entry interval.
dithiocarbamate (group M3)	mancozeb	Manzate Pro-Stick	1.1–2.25 kg	0.4–0.9 kg	1	Use high rate under severe disease pressure. Use higher rates as the crop canopy closes. 24-hr re-entry.
		Dithane DG				
		Penncozeb 80 WP				
	metiram	Polyram DF	1.1–2.25 kg	0.4–0.9 kg	1	24-hr re-entry interval. Use high rate under severe disease pressure. Use higher rates as the crop canopy closes.

¹ PHI = Pre-Harvest Interval (days).**EARLY BLIGHT**

Identification: Dark brown-to-black spots develop on infected leaves. The spots are often irregular in shape with concentric rings. Lesions are frequently surrounded by a narrow yellowish border. Symptoms appear first on the older leaves of mature plants, spreading to the younger leaves under favourable weather conditions. Infected tubers develop dark brown-to-black, slightly sunken external lesions.

Development: Temperatures between 17°C–24°C and 12 hours of leaf wetness favour early blight development. Spores are further spread by alternating periods of wet and dry weather. Humidity is needed for spore germination. Dry weather promotes the release of spores and wind dissemination.

Tuber infection occurs at harvest, primarily through cuts, bruises or wounds. Symptoms may appear after the potatoes have been stored for several months.

Management Notes: Begin the fungicide program early and ensure adequate coverage of the lower leaves. Stress conditions such as drought, insect damage, air pollution and rapid growth at tuber sizing increase the plant's susceptibility to early blight. Under these conditions, spray intervals should be shortened to 7 days. Plants infected with *Verticillium* or expressing common mosaic symptoms are particularly susceptible to early blight. See Table 9-74, *Early Blight and Late Blight Protectant Fungicide Recommendations*, on page 162.

LATE BLIGHT

If late blight is suspected in the seed, apply Curzate 60 DF + Manzate Pro-Stick at 95% crop emergence.

Identification: Initial symptoms on leaves are small, light-to-dark green, circular-to-irregular shaped, water-soaked spots. Later, the lesions become grey-to-

tan, surrounded by a light green halo. White and fuzzy mycelium develop at the edge of the lesions, usually on the underside of leaves. Under humid conditions, entire leaves can become blighted as new infections occur and existing lesions coalesce.

Late blight lesions on tubers are irregularly shaped, brown-to-purplish and slightly sunken. The size of the tuber lesions is variable. A reddish-brown, granular dry rot develops under the skin, penetrating less than 1.25 cm into the tuber. Following late blight infection, secondary bacteria infect the tubers, causing a slimy and foul-smelling rot.

The late blight fungus has two mating types, A1 and A2. Only a laboratory analysis can determine which mating type and strain are infecting a crop. Field identification is limited to "late blight." If the two mating types infect the same potato plant tissue and mate, oospores (sexual spores) are produced. Oospores are thick walled and survive in the soil for several years in a dormant state. Oospores can initiate soil-borne late blight infections. In Ontario, oospores have not been detected in potato fields.

Development: The late blight fungus overwinters in infected cull tubers, tubers left in the field after harvest and in infected seed tubers. The disease develops inside the stems and foliage of plants grown from infected tubers. Temperatures of 12°C–20°C, coupled with leaf wetness for a few hours, are ideal to initiate sporulation of the fungus on infected plants. Spores are dispersed by wind. They germinate in the presence of free water and penetrate leaves, stems and petioles, initiating new infections. Disease symptoms develop 4–6 days after infection.

Management Notes: Start a preventative fungicide program, before row closure. Keep all foliage and newly formed leaves covered. It is critical to time spray

applications so the crop is protected before infection periods or periods of wet weather occur. See *Late Blight*, opposite page. Best management practices include:

- Plant healthy seed. Tagged seed (Elite or Foundation) gives no guarantee it is not carrying late blight.
- Use a seed treatment containing mancozeb.
- Destroy cull piles (bury, chop, freeze or feed to livestock) prior to new crop emergence. Monitor cull disposal sites and treat emerging sprouts with herbicide.
- Control volunteer potatoes and host nightshade weeds growing in neighbouring fields.
- Create a good hill that ensures good tuber coverage.
- Control weeds. Weeds increase the humidity within the potato canopy, favouring the development of late blight.
- Start a preventative fungicide program early, when plants are beginning to touch along the rows.
- Scout fields twice a week. Pull, bag and remove the first infected plants found. Mark these areas with a flag and recheck.
- Disc in or top-kill any late blight hot-spots immediately.
- Switch to late blight-specific fungicides. Applications of copper are recommended to kill late blight spores on the soil that might otherwise be washed onto tubers.
- If possible, irrigate during the day to avoid prolonged periods of wet foliage at night. Do not irrigate near the end of the season if new outbreaks of late blight are noticed.
- Seal soil cracks to reduce tuber infection.
- Harvest when vines are completely dead so living spores are not sprinkled on tubers at harvest.
- Sort tubers coming into storage. Remove damaged and decaying tubers.
- Apply phosphorous acid to tubers going into storage.
- Monitor the storages frequently. Look for water condensation on the walls and ceiling. Keep the temperature and the humidity at the lowest possible levels to reduce the spread of late blight in storage.

FUSARIUM DRY ROT

Identification: Sunken or wrinkled areas develop on the surface of tubers. A dry, dark brown-to-black decay develops internally.

Development: Bruising or wounding of tubers during harvest or handling favours fusarium dry rot infection. The leading cause of potato seed piece breakdown after planting is fusarium dry rot.

Management Notes: A "bag test" is recommended on seed stock after 1 or 2 months of storage to assess the fusarium dry rot concentration. Select 20 tubers from the face of the pile, cut them in quarters if small or in eighths if larger and drop them in a new 4.5-kg potato

bag. Shake the bag vigorously for a minute to inoculate the freshly cut seed. Fold the paper bag over loosely and place it inside a plastic garbage bag. Store in a cool (16°C–18°C), dark location for 3–4 weeks.

If more than 30% of the seed pieces show fusarium dry rot infection, there is a potential high incidence of seed piece decay. See Table 9–70, *Potato Seed Piece Treatment Recommendations*, on page 158, and Table 9–76, *Potato Pythium Leak, Pink Rot, Rhizoctonia, Silver Scurf and Fusarium Dry Rot Control*, on page 164.

RHIZOCTONIA

Identification: Typical symptoms of *Rhizoctonia* diseases include stem and stolon cankers, weak, stunted plants, aerial tubers, leaf rolling, premature death of plants and tuber malformations. Black sclerotia (scurf) development on infected tuber surfaces causes serious losses for tablestock growers.

Development: *Rhizoctonia* is a common seed- and soil-borne fungus. It is more prevalent during cool, wet springs.

Management Notes: *Rhizoctonia* populations increase in soil where little or no rotation is practised. Avoid land known to be heavily infested with *Rhizoctonia*. Use clean seed, free of black scurf. See Table 9–76, *Potato Pythium Leak, Pink Rot, Rhizoctonia, Silver Scurf and Fusarium Dry Rot Control*, on page 164.

VERTICILLIUM WILT

Identification: Symptoms are usually noticeable after flowering. Infected stems often wilt during the heat of the day but recover at night. The vascular area or "woody tissue" of infected stems turns brown. As the disease progresses, the foliage turns yellow. The crop dies early, 3–4 weeks before reaching maturity. Tubers do not size, and serious yield losses occur. The presence of root lesion nematodes can further aggravate verticillium wilt.

Development: Verticillium wilt persists in the soil for many years. Short crop rotations with susceptible varieties tend to increase the population of *Verticillium* to damaging levels, especially in sandy soils. Verticillium wilt symptoms are increased by crop stress induced by high soil temperatures, drought, nutrient deficiencies and insect damage.

Management Notes: Test soils for *Verticillium* levels. If *Verticillium* and/or nematode levels are high, fumigation may be necessary. See Appendix G, *Diagnostic Services*, on page 240. Follow a long-term rotation with non-host crops. Good soil management promotes stronger, healthier potato roots.

Table 9–74. Early Blight and Late Blight Protectant Fungicide Recommendations
Begin applications prior to disease development.

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
EARLY BLIGHT ONLY						
Qol (group 11)	azoxystrobin	Quadris Flowable	500–800 mL	200–320 mL	1	Maximum 3 applications/yr. Do not apply sequential applications of any Qol fungicide or of any tank-mix containing a Qol fungicide.
Qol + chloronitrile (group 11 + M5)	azoxystrobin + chlorothalonil	Quadris Flowable + Bravo 500	500 mL + 2 L	200 mL + 800 mL	2	Maximum 3 applications/yr. Do not apply sequential applications of any Qol fungicide or of any tank-mix containing a Qol fungicide. 48-hr re-entry interval.
Qol (group 11)	pyraclostrobin	Headline EC	450–670 mL	180–268 mL	3	Rotate with a product from a different fungicide family after every application. 48-hr re-entry interval.
anilino-pyrimidine + chloronitrile (group 9 + M5)	pyrimethanil + chlorothalonil	Scala 400 SC + Bravo 500	750 mL + 1.2–2.4 L	300 mL + 0.5–1.0 L	7	Maximum 6 applications/yr. 48-hr re-entry interval.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	70–126 g	30	Do not apply more than 2 applications before rotating to a different fungicide family. 4-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	8–15 L	3–6 L	0	Suppression only.
EARLY AND LATE BLIGHT						
Qol + dithiocarbamate (group 11 + M3)	fenamidone + mancozeb	Reason 500 SC + Manzate Pro-Stick	200 mL + 1.25 kg	80 mL + 0.5 kg	14	Do not apply sequential applications of any Qol fungicide or of any tank-mix containing a Qol fungicide. 24-hr re-entry.
		Reason 500 SC + Dithane DG	200 mL + 1.17 kg	80 mL + 0.47 kg		
		Reason 500 SC + Penncozeb 80 WP	200 mL + 1.17 kg	80 mL + 0.47 kg		
Qol + chloronitrile (group 11 + M5)	fenamidone + chlorothalonil	Reason 500 SC + Bravo 500	200 mL + 1.25 L	80 mL + 500 mL		Do not apply sequential applications of any Qol fungicide or of any tank-mix containing a Qol fungicide. 48-hr re-entry interval.
Qol + acetamide (group 11 + 27)	famoxadone + cymoxanil	Tanos 50 DF	560–840 g	224–336 g	14	Do not apply sequential applications of any Qol fungicide or of any tank-mix containing a Qol fungicide. 24-hr re-entry interval.
Qol + chloronitrile (group 11 + M5)	pyraclostrobin + chlorothalonil	Headline EC + Bravo	450–670 mL + 1.2–2.4 L	180–268 mL + 0.5–1.0 L	3	Rotate with a product from a different fungicide family after every application. 48-hr re-entry interval.
Qol + dithiocarbamate (group 11 + M3)	pyraclostrobin + metiram	Headline EC + Polyram	450–670 mL + 1.1–1.75 kg	180–268 mL + 440–700 g	3	Rotate with a product from a different fungicide family after every application. 48-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).

Late Blight

Late blight has the potential to be an extremely destructive disease of potatoes in Ontario. Effective late blight control starts with a preventative spray program starting before row closure. The best management programs include broad spectrum, protectant and targeted fungicides. Always rotate between chemical groups.

The broad spectrum fungicides are listed in Table 9–73, *Potato — Broad Spectrum Protectant Fungicide Recommendations*, on page 160.

See Table 9–74, *Early Blight and Late Blight Protectant Fungicide Recommendations*, this page, for a full list of protectant fungicides recommended for early and late blight.

The strains of the late blight fungus that now prevail in Ontario are more aggressive and develop faster than in the past. If the weather is favourable for disease development and no effective fungicides are applied, late blight can destroy a potato field within a few days.

Table 9-75. Late Blight Targeted Protectant Fungicide Recommendations

Begin applications when weather conditions favour late blight, or if late blight is identified in the local area.

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
carbamate/ chloronitrile (group 28/M5)	propamocarb/ chlorothalonil	Tattoo C	2.7 L	1.1 L	7	Use 200–300 L water per ha (20–30 gal/acre). Maximum 3 applications/yr. 48-hr re-entry interval for hand labour. 4-hr re-entry interval with protection for other short-term tasks not involving hand labour.
carboxylic acid amide (group 40)	mandipropamid	Revus	400–600 L	160–240 L	14	The use of a non-ionic adjuvant (0.125% v/v) is recommended.
acetamide + dithiocarbamate (group 27 + M3)	cymoxanil + mancozeb	Curzate 60 DF + Manzate Pro-Stick	225 g + 1.6 kg	90 g + 0.65 kg	8	Make 2 applications, 5 days apart, then rotate with a late blight targeted protectant fungicide from a different chemical family. 24-hr re-entry interval.
Oil (group 21)	cyazofamid	Ranman 400SC	100–200 mL	40–80 mL	7	Maximum 6 applications/yr. Do not make sequential applications. 12-hr re-entry interval. 30-day plant-back interval. Use high rate for tuber blight protection.
benzamide + dithiocarbamate (group 22 + M3)	zoxamide + mancozeb	Gavel 75 DF	1.7–2.25 kg	0.7–0.9 kg	3	Maximum 6 applications/yr. Plant-back restrictions apply, see label for details. 48-hr re-entry interval.
pyridinamine (group 29)	fluazinam	Allegro 500 F	400 mL	160 mL	14	24-hr re-entry interval. Do not make more than 3 sequential applications.
cinnamic acid + chloronitrile (group 40 + M5)	dimethomorph + chlorothalonil	Acrobat 50 WP + Bravo 500	450 g + 1.2–2.4 L	180 g + 0.5–1.0 L	14	Maximum 3 applications/yr. 120-day plant-back interval. Apply after top kill for tuber blight protection. 48-hr re-entry interval.
cinnamic acid + dithiocarbamate (group 40 + M3)	dimethomorph + mancozeb	Acrobat 50 WP + Dithane DG	450 g + 1.1–2.25 kg	180 g + 0.4–0.9 kg	14	
	dimethomorph + metiram	Acrobat 50 WP + Polyram	450 g + 1.1–2.25 kg	180 g + 0.4–0.9 kg	14	

LATE BLIGHT TUBER INFECTION PROTECTION

inorganic (group M1)	copper hydroxide	Kocide 2000	0.8–1.6 kg	0.3–0.6 kg	1	Combine with 1.75–2.25 kg/ha (0.7–0.9 kg/acre). Manzate Pro-Stick. Use 2.4 kg/ha (1 L/acre) at vinekill.
		Parasol Flowable	0.8–1.8 L	0.32–0.7 mL	1	
	copper sulphate	Copper 53W	5.5 kg	2.2 kg	1	Copper sulphate can cause phytotoxicity, especially under hot and humid conditions. Apply close to vine killing time to kill spores of the late blight fungus.
	copper oxychloride	Copper spray	4 kg	1.6 kg	1	

¹ PHI = Pre-Harvest Interval (days).

If the weather is cool and wet, new growth should be protected against late blight at all times, even if late blight has not been found in the area. Adjust spray intervals accordingly. A 4–5-day spray interval may be necessary if the crop is growing vigorously.

Under cool, wet conditions, or if late blight has been found in the local area, use one of the fungicides listed in Table 9-75, *Late Blight Targeted Protectant Fungicide Recommendations*, this page.

If late blight is found in a field, make two applications of Curzate 60 DF tank-mixed with Manzate Pro-Stick or Bravo 500, 5 days apart. Curzate 60 DF has a 36-hour kick-back. It will kill newly germinated spores for up to 36 hour after the initial infection. After the second application of Curzate 60 DF, switch to one of the other late blight targeted protectant fungicides listed in Table 9-75.

Table 9–76. Potato Pythium Leak, Pink Rot, Rhizoctonia, Silver Scurf and Fusarium Dry Rot Control

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
In-Furrow						
phenylamide (group 4)	metalaxyl-M	Ridomil Gold 480 SL	4 mL/100 m of row	1.2 mL/100 ft of row	80	Pink rot. Apply directly over the seed pieces in-furrow.
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/100 m of row	1.2–2 mL/100 ft of row	90	Rhizoctonia stem canker, stolon canker, black scurf. Suppression of silver scurf. Apply once at planting in 50–140 L of water/ha (5–14 gal/acre). 30-day plant-back restrictions.
Foliar						
phenylamide + dithiocarbamate (group 4 + M3)	metalaxyl-M + mancozeb	Ridomil Gold MZ 68WP	2.5 kg	1 kg		Mancozeb, the protectant fungicide in this mixture, should also provide protection against early and late blight. Do not use more than 3 times per year.
phenylamide + chloronitrile (group 4 + M5)	metalaxyl-M + chlorothalonil	Ridomil Gold + Bravo Twin Pak	2.21 L (1 jug/4 ha)	0.88 L (1 jug/10 acre)		Do not use more than 3 times per year. 48-hr re-entry interval.
Post-Harvest						
dithiocarbamate (group M3)	mancozeb	Dithane F-45		1.58 L / 1,000 kg of seed		Apply to seed potatoes only prior to storage to control fusarium dry rot.
inorganic (group M1)	hydrogen peroxide	StorOx		100 mL / 10 L water		Fusarium dry rot suppression only. Apply prior to storage.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO		85–175 mL / tonne of potatoes		See product label for details.

¹ PHI = Pre-Harvest Interval (days).**PYTHIUM LEAK**

Identification: Infected tubers develop a cream-to-black watery rot. The rotted flesh is clearly separated from healthy tissue by a dark line. A clear, brownish liquid is readily released by the rotted tissue when the tuber is pressed. Pythium leak rot has a sweet smell.

Development: Pythium fungi are common to many different crops and soils. Tubers are infected through cut surfaces or bruises that occur at harvest. Pythium leak is particularly troublesome in immature potatoes harvested under warm conditions. Serious losses can also occur when tubers are handled roughly, and when crops are stored at high temperatures with poor ventilation. Pythium leak can also be a problem on cut seed in the field.

Management Notes: Minimize mechanical injury to the tubers during digging, grading and storage operations. Do not harvest when the weather is too hot. Cool tubers immediately after harvest and maintain good air movement in the storage area. See Table 9–76, *Potato Pythium Leak, Pink Rot, Rhizoctonia, Silver Scurf and Fusarium Dry Rot Control*, this page.

PINK ROT

Identification: Pink rot causes a soft, spongy rot on tubers. On exposure to the air, the infected flesh develops a pink colour and eventually turns completely black. Internal rot usually begins at the stem end and

is creamy-coloured or light brown. Wilt symptoms can occur on the foliage.

Development: Infection usually occurs before harvest. This disease is associated with excessive soil moisture, low spots in the field, over-irrigated areas and poorly drained soils. Pink rot may spread slowly in storage.

Management Notes: The varieties Russet Norkotah, Goldrush, Snowden and Kennebec are all very susceptible to pink rot. See Table 9–76, *Potato Pythium Leak, Pink Rot, Rhizoctonia, Silver Scurf and Fusarium Dry Rot Control*, this page.

BLACKLEG

Identification: Infected seed and sprouts often rot before or soon after emergence, resulting in uneven stands. If the spring weather favours rapid emergence, infected seed will produce weakened, stunted plants. Infected stems show an inky black decay extending up from the infected seed piece. Leaves tend to wilt and to roll upward at the margins.

Development: The blackleg bacterium is primarily seed-borne. Wet weather and excessive soil moisture favour disease development.

Management Notes: Plant higher generation seed. Poor sanitation and seed-cutting practices may increase

blackleg incidence. Disinfect cutting knives often during seed cutting. Monona, Chieftain and Dakota Pearl are very susceptible to blackleg.

COMMON SCAB

Identification: Scab lesions on tubers vary in extent and appearance. They include superficial corky spots, raised corky lesions or pitted lesions. Severe pitted scab results in cavities as deep as 1 cm. As tubers increase in size, the lesions expand and scab severity increases.

Development: Warm, dry soils during and after tuber-set are conducive to scab development. A soil pH from 6–7.5 is most favourable for common scab. The acid-tolerant scab species (*S. acidiscabies*) can infect tubers in soils with pH as low as 5.

Management Notes: Avoid planting scabby seed. If possible, choose tolerant cultivars such as Superior, Onaway, Norland, Dakota Pearl and Pike. Avoid heavy applications of limestone. Where irrigation is available, maintain high soil moisture for 4 weeks after tuber setting begins. The application of organic amendments reduces the incidence of scab.

BACTERIAL RING ROT (BRR)

Identification: The type of symptoms expressed by BRR vary, depending on the variety. Infected plants may not show symptoms if the weather is cool and wet. The leaflet tissues turn yellow between the veins. Stems and leaves wilt. Infected tubers develop a creamy-brown, cheesy, odourless rot.

Development: Ring rot develops rapidly when soils are dry and temperatures range from 24°C–32°C. The ring rot bacterium can survive for up to 2 years as dried slime on cutting knives, storage bins, equipment, bags, etc.

Management Notes: Use pedigreed seed that has had a BRR lab test. Practice complete cleanliness. See *Storage Sanitation*, on page 50.

Zero tolerance control measures are in place against this disease. The seed potato regulations in Canada¹ indicate that upon a finding of bacterial ring rot, all lots under cultivation by the grower are rejected for certification.

¹ CFIA D-95-18: Seed Potato Certification Program — Investigation Procedure After *Clavibacter michiganensis* subsp. *sepedonicus* Has Been Detected on a Seed Potato Farming Unit.

LEAF ROLL AND NET NECROSIS

Identification: Seed-borne infections cause stunted plants with rolled-up lower leaves. Affected leaves are pale and have a leathery texture. Lower leaves

eventually die, and upper leaves turn yellow. Yield is reduced in both tuber numbers and tuber size.

Aphid-transmitted infections have similar but less severe symptoms. In some varieties, notably Russet Burbank and CalWhite, late-season infections may cause net necrosis in daughter tubers, rendering them unmarketable. Shepody is slightly susceptible.

Development: Several species of aphids can transmit the leaf roll virus, but the green peach aphid seems to be the most common vector. Infected seed, sprouted cull potatoes and volunteers are the main overwintering sources of leaf roll. Winged aphids spread the virus over long distances.

Management Notes: Control aphids by scouting fields and spraying. Use varieties resistant to net necrosis. Plant pedigreed seed indicating low levels or absence of this disease.

Physiological Disorders

PINK EYE

For many years, pink eye was thought to be caused by bacteria. However, recent scientific reports suggest that pink eye is a physiological disorder.

Pink eye is characterized by skin-deep, pinkish blotches near the eyes of the stem end. The skin of affected tubers dries and cracks easily. Internal reddish-brown to black discolouration, cavities and secondary soft rots are often associated with severe pink eye. Pink eye occurs sporadically. It usually develops late in the growing season under conditions of high soil moisture.

Management Notes: Increase air flow through the pile to promote drying of pink-eye lesions. Pink eye is often associated with *Verticillium* and *Rhizoctonia*. Good control of these fungi will reduce the incidence of pink eye. Varieties such as Kennebec and Superior are very susceptible to pink eye.

BROWN CENTRE AND HOLLOW HEART

Brown centre is associated with cool, wet soil conditions during tuber initiation and/or periods of rapid tuber growth. Pith tissues near the centre of the tuber become light-to-dark brown. The affected cells eventually die.

Hollow heart is common in oversized or rapidly growing tubers. A single large cavity or several smaller cavities develop in the tuber. Cavity size can range from less than 1 cm to a large area that includes the whole pith tissue. This disorder is more severe under conditions that favour rapid tuber enlargement, such as fluctuating soil moisture levels. Wide plant spacings can increase the

Table 9–77. Potato Aphid Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
Soil Application						
neonicotinoid ² (group 4)	imidacloprid	Admire 240 F	0.85–1.3 L ³	0.34–0.5 L ³	7	Also controls leafhoppers and fleabeetles. 24-hr re-entry interval.
		Alias 240 EC				
		Grapple				
	thiamethoxam	Actara 240 SC	378–488.9 mL ³	153–198 mL ³	90	Also controls leafhoppers. Maximum 1 application/yr.
Foliar Applications						
pyridine	pymetrozine	Fulfill 50WG ⁴	193 g	78 g	14	12-hr re-entry interval. Maximum 2 applications/yr.
neonicotinoid ² (group 4)	imidacloprid	Admire 240 F	200 mL	81 mL	7	Maximum 2 applications/yr for all uses. 24-hr re-entry interval.
		Alias 240 EC				
		Grapple				
	acetamiprid	Assail	56–86 g	23–35 g	7	Do not make more than 2 applications/yr. 12-hr re-entry interval.
	thiamethoxam	Actara 25 WG	105 g	42 g	7	Also controls leafhoppers. Maximum 2 applications/yr. 12-hr re-entry interval.
tetrionic and tetramic acid derivatives (group 23)	spirotetramat	Movento	220–365 mL	89–148 mL	7	Most effective on young stages. Has slow activity; control may not be apparent for 2–3 weeks. 12-hr re-entry interval.
organophosphate (group 18)	dimethoate	Cygon 480	0.55–1.1 L	0.22–0.4 L	7	
		Lagon 480				
	methamidophos	Monitor 480	1.75–2.25 L	0.7–0.9 L	14	Also controls leafhoppers, tarnished plant bugs and flea beetles. It can be effective against Colorado potato beetle in areas where this insect has not developed resistance to this insecticide yet. 48-hr re-entry interval.
	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	21	Green peach and potato aphids only. Maximum 4 applications/yr. 12-hr re-entry.
	oxamyl	Vydate L	2.3–3.0 L	0.9–1.2 L	7	Green peach and potato aphids only. 24-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).² Do not apply a neonicotinoid foliar spray in fields where a neonicotinoid was used either in-furrow or as a seed treatment.³ Based on 90-cm row spacing.⁴ Fulfill 50WG causes cessation of aphid feeding shortly after application. However, aphids may remain on the plant for 2–4 days before they die.

incidence of hollow heart. Tubers with boron deficiency are prone to hollow heart. The varieties Atlantic and Yukon Gold are very susceptible to hollow heart.

HEAT NECROSIS

Heat necrosis occurs when a period of slow tuber growth is followed by sudden, high temperatures. Tubers develop round or irregular necrotic spots or blotches in the vascular tissue area. Affected tissue ranges from light tan or reddish-brown to rust-coloured. There are no external symptoms of heat necrosis. The varieties Atlantic and Chieftain are very susceptible to heat necrosis.

Insects

WIREWORMS, APHIDS, CUTWORMS, TARNISHED PLANT BUG

For identification and management information on these common vegetable insects affecting potatoes, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, Table 9–77, *Potato Aphid Control Recommendations*, this page, and Table 9–78, *Potato Insect Control Recommendations*, opposite page.

POTATO LEAFHOPPER

Identification: The adult leafhopper is yellow-green, wedge-shaped and approximately 3 mm long. Adults are very active and quick to fly. Immature nymphs are smaller and wingless. When disturbed, nymphs quickly move forward or sideways. Both the adults and the

Table 9–78. Potato Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
POTATO LEAFHOPPER, FLEA BEETLES, TARNISHED PLANT BUG						
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	83 mL	34 mL	7	Also controls European corn borer. Maximum 3 ground applications or 2 aerial applications/yr. 24-hr re-entry interval.
		Silencer 120 EC				
	deltamethrin	Decis 5 EC	100–150 mL	40–61 mL	3	Maximum 3 applications/yr.
	permethrin	Pounce 384 EC	180–260 mL	73–105 mL	1	Use higher rate for heavy infestations. Also controls European corn borer. 12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC	140–200mL	57–81 mL		
	cypermethrin	Ripcord 400 EC	62.5–125 mL	25.3–51 mL	7	Use high rate on tarnished plant bug.
UP-Cyde 2.5 EC		140 mL	57 mL	7	Use 200 mL/ha or 40 mL/acre for tarnished plant bug. 12-hr re-entry interval.	
organophosphate (group 1B)	dimethoate	Lagon 480	0.55–1.1 L	0.22–0.4 L	7	Leafhoppers only.
		Cygon 480				
	naled	Dibrom	1.1 L	0.4 L	4	Not for tarnished plant bug. 48-hr re-entry interval.
	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	21	Maximum 4 applications/yr. 24-hr re-entry.
	chlorpyrifos	Lorsban 4E	1.0 L	0.4 L	7	Not for leafhopper. 24-hr re-entry interval.
Pyrinex 480 EC						
carbamate (group 1A)	oxamyl	Vydate L	2.3–3.0 L	0.9–1.2 L	7	24-hr re-entry interval.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–1.5 kg	0.4–0.6 kg	1	Use high rates for tarnished plant bug.
		Thiodan 4 EC	1.5–2.0 L	0.6–0.8 L	1	
		Thionex 50 WP	1.1–1.75 kg	0.4–0.7 kg	1	
	kaolin	Surround WP	6.25–12.5 kg	2.5–5.1 kg		For suppression of leafhoppers only. For early applications, use the higher labelled rate per 250 L of water; follow-up applications may only require the lower labelled rate per 250 L of water.
LATE-SEASON CUTWORMS						
pyrethroid (group 4)	cypermethrin	Ripcord 400 EC	175 mL	70 mL	7	
organophosphate (group 1B)	chlorpyrifos	Lorsban 4 E	1.2–2.4 L	0.5–1 L	7	Apply in early evening for maximum control. 24-hr re-entry interval.
		Pyrinex 480 EC				
	permethrin	Ambush 500 EC	140–200 mL	57–81 mL	1	Variegated cutworm. Use high rate on dry soils or large larvae. Apply up to 5-leaf stage. Do not disturb ground for 5 days following application. 12-hr re-entry interval.
Perm-UP		180 mL	73 mL			
SPIDER MITES						
Group 6	abamectin	Agri-Meck 1.9% EC	1 L	404 mL	14	Apply in 185 L of water/ha or 74 L of water/acre. Apply when spider mites first appear.

¹ PHI = Pre-Harvest Interval (days).

¹ PHI = Pre-Harvest Interval (days).

nymphs feed on potatoes, causing leaf puckering and browning of the leaf margins ("hopperburn"). Hopperburn is often confused with drought stress.

Period of Activity: Leafhoppers migrate to Ontario in the early spring. Initial generations feed on alfalfa before moving into other crops, such as potatoes.

Thresholds: 1 nymph or adult per 2 plants

Management Notes: Leafhopper populations can increase rapidly in warm weather. Field scouting is the first line of defence against this insect. Where potatoes are planted in the vicinity of an alfalfa field, scout twice weekly. See Table 9–78, *Potato Insect Control Recommendations*, this page.

COLORADO POTATO BEETLE

Identification: Bright-yellow eggs are laid in clusters, usually on the underside of leaves. Larvae are orange-red with a distinct black head, humped back and a double row of black dots on each side of their bodies. Adult potato beetles are orange with 10 black stripes on their wings.

Period of Activity: In Ontario, the Colorado potato beetle (CPB) usually completes two generations during the growing season. In warm summers, a third generation may develop.

Adult beetles overwinter in the field or in surrounding, protected areas. Egg-laying occurs shortly after emergence. If spring weather is warm, beetle emergence is often very rapid. During cool springs, beetle emergence becomes more staggered. Females lay eggs for a 4–5-week period.

Eggs hatch into larvae within 4–9 days, depending on temperature. The larvae pass through 4 stages (instars), reaching maturity in 7–20 days. The pupal stage lasts 5–9 days, after which the next generation of adults emerges. The second-generation beetles feed continuously to accumulate enough energy to survive the winter buried in the soil.

Thresholds: One adult or larvae per plant warrants control.

Management Notes: This insect has developed resistance to most of the insecticides registered for its control. See *Resistance Management*, on page 54.

To delay the development of resistance in CPB populations, rotate fields so that beetles must walk or fly from overwintering sites to newly planted fields. This takes time, and many beetles die before reaching the new crop. Plastic-lined ditches may be used to trap emerging adults as they walk towards the potato crop from overwintering sites. Propane flammings may also be used on border rows or whole fields until the crop is 15 cm high.

Small CPB larvae are much easier to control than adult beetles or large larvae. See Table 9–79, *Potato Colorado Potato Beetle Control Recommendations*, opposite page.

Dip tests are recommended before spraying any insecticide because of the high levels of resistance found in CPB populations. Dip tests are very effective in determining which insecticide should provide the best control in your fields. For more information on dip tests, visit the OMAFRA website at www.ontario.ca/crops or call the Agricultural Contact Centre at 1-877-424-1300.

Caution: The Colorado Potato beetle (CPB) has the ability to develop resistance to insecticides very rapidly. Several insecticides recommended for CPB control belong to the neonicotinoid chemical family. To delay the development of resistance to neonicotinoids, the following practices are strongly recommended:

Do not apply a neonicotinoid foliar spray in fields where a neonicotinoid was used either in-furrow or as a seed treatment.

- Use label rates.
- Scout fields regularly to evaluate the efficacy of insecticide treatments.
- If control of CPB is poor after an insecticide application, collect CPB samples and have them tested for resistance.

CPB has developed resistance to most of the pyrethroid insecticides. It is strongly recommended that a backpack spray test be conducted in a small area of the field before applying a pyrethroid to the entire field.

Nematode Control

See *Nematodes*, on page 63, for control recommendations.

Sprout Inhibition

After completion of a rest (dormancy) period, potatoes sprout readily. Potatoes treated with chemical sprout inhibitors can be stored at 10°C or higher without sprouting.

Field-Applied

Maleic hydrazide is a plant-growth regulator, applied in the field to control sprouting of potatoes in storage. It should be applied in a manner that ensures complete and uniform coverage. For example, apply Royal MH 60 SG at a rate of 5.65 kg in 300 L of water/ha.

Timing is important. Recent research has shown that too early an application on some cultivars may result in phytotoxicity and reduced potato size. Consult manufacturer's recommendations for more detailed information on both rates and timing. Time of application may occur as early as 2–3 weeks past full bloom. Only apply to plants that are green and free from insects, disease and other damage.

Once in storage, tubers treated with maleic hydrazide will not affect seed potatoes stored in the same storage. Crates formerly used for the storage of maleic hydrazide-treated tubers will not affect seed potatoes.

Table 9-79. Potato Colorado Potato Beetle Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
Soil Treatments						
neonicotinoid (group 4)	imidacloprid	Admire 240 F ²	0.85–1.3 L ³	0.34–0.53 L ³	90	Use 7.5–12 mL per 100 m of row. For best results, spray directly on the seed piece.
		Grapple ²				
	thiamethoxam	Actara 240 SC ²	378–488.9 mL ³	153–197.9 mL ³		Will also control leafhoppers. Maximum 1 application/yr.
	clothianidin	Clutch 50 WDG ²	266–448 g	108–181 g		
Foliar Sprays						
biological (group 11)	<i>Bacillus thuringiensis</i>	Novodor	5.0–8.0 L	2–3.2 L	1	For 1st and early 2nd instar Colorado beetle larvae only; other stages and other insects not controlled. Field scouting is essential for timing the sprays.
neonicotinoid (group 4)	imidacloprid	Admire 240 F	200 mL	81 mL	7	Maximum 2 foliar applications/yr. 24-hr re-entry interval.
		Grapple				
	acetamiprid	Assail 70 WP	40–80 g	16–32 g	7	Maximum 2 applications/yr. 12-hr re-entry interval.
	clothianidin	Clutch 50 WDG	70–105 g	28–42 g	14	
	thiamethoxam	Actara 25 WG	105 g	42 g	7	Will also control leafhoppers. Maximum 2 applications/yr. 12-hr re-entry interval.
		Actara 240 SC	109 mL	44 mL		
diamides (group 28)	chlorantraniliprole	Coragen	250–375 mL	101–151 mL		Early applications on larval stages provide best control. Will also control European corn borer. 12-hr re-entry interval.
spinosyn (group 5)	spinosad	Success 480 SC	166 mL	67 mL	7	Will also control European corn borer. Maximum 240 mL of product per year. 12-hr re-entry interval.
		Entrust 80W	50–100g	20–40 g	7	Will also control European corn borer (small larvae). Maximum 2 applications/yr. Maintain a spray pH of 6 or greater. 12-hr re-entry interval.
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83–125 mL	34–51 mL	7	Use the higher rate for larger instars and infestations. Maximum 3 applications/yr at the low rate or 2 applications/yr at the high rate. Do not exceed 250 mL/ha (100 mL/acre)/yr. 24-hr re-entry interval.
		Silencer 120 EC				
	cypermethrin	Ripcord 400 EC	62.5–125 mL	25.3–51 mL	7	
		UP Cyde 2.5 EC	140mL	57 mL	7	12-hr re-entry interval.
	permethrin	Perm-UP	180–260 mL	73–105 mL	7	12-hr re-entry interval.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–1.5 kg	0.4–0.6 kg	1	
		Thiodan 4 EC	1.5–2.0 L	0.6–0.8 L	1	
		Thionex 50 WP	1.1–1.5 kg	0.4–0.6 kg	1	
carbamate (group 1A)	oxamyl	Vydate L	2.3–3.0 L	0.9–1.2 L	7	24-hr re-entry interval.
organophosphate (group 1B)	naled	Dibrom	1.1 L	0.4 L	4	48-hr re-entry interval.
benzoylurea (group 15)	novaluron	Rimon 10 EC	410–820 mL	166–332 mL	14	Maximum 2 applications/yr. Apply at egg hatch to second instar. Also controls European corn borer (small larvae).

¹ PHI = Pre-Harvest Interval (days).² See Caution sidebar on facing page.³ Based on 90-cm row spacing.

Storage-Applied

CIPC (chlorpropham) is also widely used for sprout inhibition. Apply it in storage as a dip, spray or aerosol just before sprouting starts. Potato tubers may be treated with this chemical before packaging for market. Do not apply CIPC at harvest time. Application as a gas to storage bins must be performed by a licensed applicator.

To use CIPC in packing lines, prepare 1 L of Sprout Nip EC in 35 L of water and stir to make an emulsion. Use 1 L of this emulsion per tonne of potatoes.

Do not use either of these treatments on potatoes grown for seed. Do not store seed potatoes in the same storage as CIPC-treated tubers or in crates that were in the storage when CIPC was applied.

Vine Killing

Vine killing is especially important to seed growers. An early kill controls tuber size and reduces the spread of virus diseases by aphids.

Chemical vine killers are not recommended for early potatoes. They limit the yield, size and dry-matter content without reducing skinning. However, where it is necessary to control size to reduce hollow heart, chemical vine killing may be of value for early potato crops.

Use Reglone (Diquat) as follows:

Heavy green top growth and weeds:	3.5 L/ha (1.4 L/acre)
Medium top growth or crop beginning to mature:	1.7–2.3 L/ha (0.7–0.9 L/acre)
Split application:	1.25–2.3 L/ha (0.5–0.9 L/acre) followed by 1.5 L/ha (0.6 L/acre) in 5–6 days

Apply in at least 550–1,100 L/ha of clean water. Muddy water may inactivate Reglone. Allow 14–21 days after application until harvest to allow proper vine desiccation and tuber skin set.

Over-application or conditions that lead to very rapid kill may cause darkening at the stem end of the tuber.

Aircraft application of Reglone is not recommended. Ensure that no drift occurs from any of these materials to adjacent crops. The residue of these compounds on other crops may result in their seizure.

The product Ignite (glufosinate ammonium) is labelled as a dessicant on table stock and processing potatoes. Do not apply to potatoes grown for seed. Apply 3.0 L in 110–220 L water/ha (1.2 L in 10–20 gal water/acre). Use the higher rate of water when the crop canopy is dense. Apply to potato vines 14–21 days prior to harvest. Symptoms of dessication will appear within 2–4 days of applying Ignite.

The product "Des-I-Cate" (endothall) is also labelled. Apply to potato vines 10–14 days prior to harvest. Apply 17–22 L/ha (6.8–8.8 L/acre.) Use the high rate for medium to heavy vine growth and during cool (less than 21°C), cloudy weather.

The use of roto-beaters is not recommended except where dead vines or weeds are a hindrance to the digger.

Storage

Store seed tubers separately from tablestock potatoes, in a disinfected storage area. Do not store seed potatoes in the same storage area as CIPC-treated tubers.

Healing of cuts and bruises is most rapid at a tuber temperature of 15°C–21°C. It is desirable to provide this temperature for 2–3 weeks at the beginning of the storage period. After this, the temperature should be lowered to 5°C if potatoes are intended for tablestock or seed.

Potatoes intended for processing should be maintained at 10°C and should never be subjected to temperatures below 5°C. It will be necessary to use a sprout inhibitor if potatoes are to be stored at 10°C for an extended period.

The relative humidity in the storage should be as high as possible without causing condensation of moisture on tubers and the storage structure. However, if soft rot is prevalent or if the tubers are wet when first put into storage, the humidity should be kept down until the tubers dry. For more information, see *Cooling and Storage*, on page 47.

RADISHES

Production Requirements

Radishes are a cool-season crop. For best results, plant into sandy loam soils with a pH of 6.5. The ideal pH for muck soils is 5.1–5.5. Radishes are adversely affected by hot, dry weather and long days. Roots grown rapidly, with plenty of moisture, are mild, tender and attractive. Slow-growing roots become hot, tough and pithy. Long days (15 hr) and high temperatures result in misshapen roots, long tops and increased seed stalk production. Most radish varieties are ready for harvest within 30–35 days of planting.

Recommended rotational crops: lettuce, tomatoes, peppers, spinach

Do not rotate with: other brassica crops, carrots, potatoes, beets

Average Yields

Crop	per acre	per hectare
Radishes with tops	4–7 tons	9–16 tonnes

Cultivars

The most popular cultivars have globe-shaped roots, red skins and leaves that are short-to-medium in length. Medium-top varieties are preferable for early spring crops. Short-top varieties are better adapted for growth during the longer-day period. Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

Radish seed can be sown as soon as the soil is workable. The minimum soil temperature required for seed germination is 4°C–7°C. Spring frosts or even snowfalls do not seriously injure the crop after the plants have emerged. Under favourable weather conditions, radish seedlings emerge 2 or 3 days after sowing. Sowing at regular intervals in the spring will provide a continuous harvest.

	Hand Harvest		Machine Harvest	
Row spacing	20–30 cm	8–12 in.	10–15 cm	4–6 in.
In-row spacing	2–2.5 cm	1 in.	2–2.5 cm	1 in.
Rate	11–17 kg/ha	10–15 lb/acre	22–34 kg/ha	20–30 lb/acre
Depth	1.5 cm	½ in.	1.5 cm	½ in.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

On mineral soils, apply up to 60 kg N/ha. On muck soils, apply 40 kg N/ha.

Phosphorus

Test the soil to determine phosphorus requirements. On mineral soils where the soil test values are 51 mg P per L soil (ppm) or higher, radishes are unlikely to respond to additional phosphate applications. For soils testing lower than 51 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

On muck soils, radishes are unlikely to respond to additional phosphate fertilizers if the soil test values are 61 mg P per L soil (ppm) or higher. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, radishes grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, and Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate prior to planting.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Boron deficiencies on radish result in splitting and cracking of the skin. Calcium deficiencies cause a backward cupping of leaves and discolouration of the leaf margins. Magnesium and manganese deficiencies appear as bronzing or yellowing of leaf tissue between the veins.

Table 9–80. Radish Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL/ 100 kg seed	pythium damping-off	For use in commercial seed-treatment plants only.
Thiram 75 WP	thiram	90 g/ 25 kg seed	seed decay and damping-off	Seed box treatment.

Also see Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16. Use caution when applying boron as it can build to toxic levels quite quickly, harming rotational crops.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario*, contains a section on radish, illustrating many of the common diseases and insect pests.

Diseases

DAMPING-OFF AND ROOT ROTS (INCLUDING RHIZOCTONIA)

Deep planting and excessive irrigation increase the risk of damping-off and root rots. For more information, see *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59, Table 9–80, *Radish Seed Treatments*, this page, and Table 9–81, *Radish Insect and Disease Control Recommendations*, opposite page.

DOWNY MILDEW

Identification: Symptoms appear as yellow spots on the upper leaf surfaces. Greyish-white fungi may be found on the underside of leaves. Downy mildew infections on the roots cause dark, discoloured areas extending from the crown, down the root. Infected roots may split or become invaded by secondary rot organisms.

Development: Infection can occur at any growth stage. Cool, moist conditions favour disease development. Downy mildew progresses rapidly at temperatures of 10°C–15°C during periods of prolonged leaf wetness, caused by rain, heavy dews or fog.

Management Notes: Downy mildew fungi can survive for least 1 yr in the soil and 2 yr on infected seed. Plant into well-drained soils and follow a 2–3-year rotation with non-brassica crops. Downy mildew-resistant

cultivars are available. Avoid excessive use of overhead irrigation. See Table 9–81, *Radish Insect and Disease Control Recommendations*, opposite page.

FUSARIUM WILT (YELLOW)

Identification: Infected seedlings rapidly turn yellow and then brown. Infections occurring later in the season cause severely weakened plants with spongy or hollow roots. The vascular tissue of infected roots becomes yellowish-brown.

Development: Fusarium wilt grows best at soil temperatures of 27°C–29°C.

Management Notes: Fusarium wilt is both soil- and seed-borne. Use certified, treated seed and follow a 2–3-year crop rotation. Resistant cultivars are available. This disease is less common on high pH (alkaline) soils. Maintain a balanced soil pH.

BLACK ROOT

Identification: Infected seedlings die back. Late-season infections cause stunted plants and blackening on both the exterior and interior of the radish root. Black root infection usually begins as a dry rot. Secondary bacterial rots eventually cause the disintegration of the root.

Development: This soil-borne disease is favoured by moist, warm soil conditions. Infection occurs between 16°C–32°C, with maximum damage at 27°C.

Management Notes: Plant into well-drained soils; follow a 4-year rotation with unrelated crops. Control all brassica weeds (wild mustard, yellow rocket, etc.). Resistant cultivars are available. Deep-plow infested residue.

SCAB

Identification: Pitted, corky, scale-like spots develop on infected roots. Lesions frequently enlarge to 1–2 cm in size and have raised edges.

Development: This soil-borne bacterial disease is favoured by dry soil conditions and high soil pH levels.

Management Notes: Do not grow radish in rotation with potato, carrot or beets. Rotations with grains are partially effective at reducing scab levels in the soil. Maintaining high soil moisture levels during root development may reduce infection.

Table 9–81. Radish Insect and Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ALTERNARIA, POWDERY MILDEW						
QoI (group 11)	pyraclostrobin	Cabrio EG	0.56–1.1 kg	226–445 g	3	Maximum 3 applications/yr. 72-hr re-entry interval (hand thinning).
RHIZOCTONIA – ROOT ROT, CROWN ROT, STEM CANKER						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/ 100 m of row	1.2–1.8 mL/ 100 ft of row	15	Maximum 1 application/yr; applied in-furrow at planting or banded soon after emergence.
CABBAGE MAGGOT						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E Pyrinex 480 EC	85 mL in 380 L water/ 1,000 m of row	26 mL in 30 gal water/ 1,000 ft of row	21	Radish. Apply as a drench at time of seeding. 24-hr re-entry interval.
			210 mL in 1,000 L water/ 1,000 m of row	63 mL in 79 gal water/ 1,000 ft of row	32	Asian radish (lo bok, daikon). Maximum 3 applications/yr. Apply as a drench at 7, 20 and 35 days after seeding. 24-hr re-entry interval.
FLEA BEETLES						
pyrethroid (group 3)	permethrin	Pounce 384 EC	180 mL	73 mL	2	12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC	140 mL	57 mL	2	
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	7	
APHIDS						
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.4 kg	10	Control of aphids with these products has been inconsistent in many areas.
		Diazinon 500 E	1.1 L	0.4 L	10	
	malathion	Malathion 500 E	1.4–3.0 L	0.6–1.2 L	7	
CABBAGE LOOPER, IMPORTED CABBAGEWORM, DIAMONDBACK MOTH						
spinosyn (group 5)	spinosad	Success 480 SC	182 mL	74 mL	3	Maximum 3 applications/yr.
		Entrust 80W	109 g	44 g	3	Maintain a spray pH of 6 or higher.
	spinetoram	Delegate WG	140–200 g	57–81 g	3	Radish and Oriental radish. Maximum 3 applications/ yr. Use the higher rate for high infestations or advanced growth stages of the target pest.
biologicals (group 11)	<i>Bacillus thuringiensis</i>	Dipel 2X DF	55–550 g	22–223 g	0	Asian radish (lo bok, daikon) only. Use 275–550 g/ha (111–223 g/acre) for loopers.

¹ PHI = Pre-Harvest Interval (days).**OTHER DISEASES**

Radishes may be infected by other diseases, such as clubroot, alternaria leaf spot, white rust and turnip mosaic virus (TuMV). For more information, see *Clubroot*, on page 86, *Alternaria (Black Leaf Spot)*, on page 86, and *Turnip Mosaic Virus (TuMV)*, on page 178.

Insects**APHIDS, CUTWORMS, MILLIPEDES**

For identification and management information on these common vegetable insects affecting radishes, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–81, *Radish Insect and Disease Control Recommendations*, this page.

CABBAGE MAGGOT, CABBAGE LOOPER AND FLEA BEETLES

Several common brassica crop insect pests also attack radishes. Cabbage maggot larvae feed on radish roots,

causing serious economic damage. Flea beetles feed on radish tops, rendering them unmarketable. Cabbage looper and other caterpillars are occasional pests of radishes. For identification and management information, see *Insects*, on page 86, and Table 9–81, *Radish Insect and Disease Control Recommendations*, this page.

Harvest and Storage

Radish quality is at its best May, June, September and October. Radishes remain in prime condition for only a few days and must be picked frequently. Bunched radishes are hand-harvested. Topped radishes may be harvested by hand or mechanically.

Remove the field heat from the crop immediately after harvest. At 0°C and a relative humidity of 95%–100%, radishes have a shelf life of up to 3–4 weeks. For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

RHUBARB

Production Requirements

Rhubarb is a cool-season, perennial vegetable crop. It performs well in deep, well-drained soils. In the spring, growth begins when soil temperatures reach 7°C. Temperatures above 26°C cause leaf decline and seed stalk development during the months of July and August.

Rhubarb can be grown in the winter as a “forced” crop. Two-year-old crowns are moved inside for the winter. They require a dormancy period where temperatures are held below 5°C for 7–9 weeks. Temperatures of 13°C–18°C will initiate growth. Force rhubarb crowns in the dark, to prevent chlorophyll development. The use of gibberellic acid (Activol GA) is recommended to decrease the required dormancy period. Consult the label for details.

Average Yields

	per acre	per hectare
Fresh market & processing (15–20 stalks per crown)	12–15 tons	27–33 tonnes

Cultivars

Red stalks are preferred by most markets. While colour is often variety dependent, it is also affected by temperature. The red colour is more pronounced in stalks grown in relatively cool weather conditions. As the temperatures increase, the green colour predominates.

A list of rhubarb crown suppliers is available on the OMAFRA website at www.ontario.ca/crops. Paper copies are available by calling the Agricultural Information Contact Centre at 1-877-424-1300.

Planting and Spacing

Row Spacing:	90–150 cm (30–60 in.)
In-row Spacing:	60–130 cm (24–48 in.)
Depth:	30–40 cm (12–15 in.)

Plant crowns in a furrow with the buds facing up. Cover the tip of each crown with at least 2.5–5 cm of soil.

As crowns age, the bud development moves from the centre of the plant to the edges. If crowns are left undivided, the centre portion will become unproductive. Eventually it will rot and die, drastically reducing the overall productivity of the field. The best productivity occurs in the first 8–10 years after planting.

Flower Stalk Removal

Flower stalk development reduces plant vigour and depletes valuable resources from the crown. Remove stalks while they are still small and before the flowers open.

Fertility Nitrogen

See Table 9–82, *Rhubarb Nitrogen Recommendations*, this page.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, rhubarb plants are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Band the phosphate below the crowns at planting.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, rhubarb plants are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Table 9–82. Rhubarb Nitrogen Recommendations

Application Time	Actual N kg/ha
Field-Grown	
Preplanting	100
Annually	
Early spring	100
After harvest	100
Total	200
Crowns for Forcing	
Early spring	100
July ¹	180
Total	280

¹ As much as 100 kg N/ha of the nitrogen recommendations may be applied through the fertigation system after harvest or in July.

Table 9-83. Rhubarb Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
APHIDS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	23–35 g	7	Maximum 5 applications/yr. 12-hr re-entry interval.
tetronic and tetramic acid derivatives (group 23)	spirotetramat	Movento	220–365 mL	89–148 mL	3	Most effective on young stages. Has slow activity; control may not be apparent for 2–3 weeks. 12-hr re-entry interval.
POTATO STEM BORER AND CABBAGE LOOPER						
spinosyn (group 5)	spinosad	Entrust 80W	109 g	44 g	1	Potato Stem Borer.
		Success 480 SC	182 mL	74 mL	1	Maximum 3 applications/yr. Maintain a spray pH of 6 or higher.
	spinetoram	Delegate WG	140–200 g	57–81 g	1	Cabbage Looper. Use the high rate for heavy infestations or large larvae. Maximum 3 applications/yr.

¹ PHI = Pre-Harvest Interval (days).

Integrated Pest Management Diseases

CROWN ROT AND VIRUS DISEASE

Crown rot infections cause sunken, brown lesions on the base of the stalks. Leaves wilt and die. Infected crowns are very susceptible to secondary bacterial soft rots. The fungi causing crown rot are common to many vegetable crops. Allow for at least 2–3 years between growing vegetables and establishing rhubarb.

Virus diseases cause yellow mottling and spots on the leaves of infected plants. Plants become stunted.

Mark the plants with vigorous growth in June. Use these crowns as planting stock the following spring. Remove and discard all unhealthy crowns.

Insects

APHIDS

For information on identification and management, see *Aphids*, on page 60, and Table 9-83, *Rhubarb Insect Control Recommendations*, this page.

POTATO STEM BORER AND CABBAGE LOOPER

The potato stem borer and the cabbage looper are both occasional pests in Ontario.

The potato stem borer overwinters as eggs on weedy grasses. The larvae hatch in mid-May. As they mature, the larvae move to larger-stalked plants such as corn, potatoes, tomatoes and rhubarb, attacking the stems and the crowns of affected plants. Larvae feed until mid-summer, at which time they pupate.

Control grassy weeds in and around rhubarb plantings.

See *Imported Cabbageworm*, *Cabbage Looper*, *Diamondback Moth Caterpillar*, on page 91.

Chemical controls are most effective on small larvae. Control of the potato stem borer must occur before they bore into the plant. See Table 9-83, *Rhubarb Insect Control Recommendations*, this page.

RHUBARB CURCULIO

The rust-coloured rhubarb curculio feeds on stalks, crowns and roots. It overwinters on curl dock. Destroy dock weeds near the rhubarb planting.

Nematode Control

See *Nematodes*, on page 63.

Harvest and Storage

Much like asparagus, a limited harvest may occur in the second spring after planting. Remove leaf blades for marketing. Leaves contain oxalic acid and are poisonous to humans.

Store rhubarb at 0°C for up to 2–4 weeks. Maintain a relative humidity (RH) of 95%. Stalks are very susceptible to dehydration.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

RUTABAGAS

Production Requirements

Rutabagas grow in a wide range of mineral soil types but perform best on a deep, well-drained loam or sandy loam soil with a pH of 6.1–6.5. For clubroot control, a higher pH is required. A frost-hardy crop, rutabagas experience their best growth during cool, fall weather conditions. Rutabagas require about 90 days from planting to harvest.

Recommended rotational crops: cereal crops, potatoes, peppers, tomatoes

Do not rotate with: other brassica crops, including canola

Average Yields

Crop	per acre	per hectare
Rutabagas	500–600 bu	1,250–1,500 bu

Cultivars

The recommended rutabaga cultivars are the Laurentian strains. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

The optimum soil temperature for germination is from 16°C–29°C. There is a very limited market for early rutabaga crops, seeded in April and May. Seed the main crop, grown for winter storage, from mid-June to early July. Rutabagas sown during this time can size up during the cool, fall weather, resulting in improved root quality.

	Metric	Imperial
Row spacing:	60–90 cm	24–36 in.
In-row spacing ¹ :	13–15 cm	5–6 in.
Depth:	1.5 cm	0.5 in.
Rate:	approx. 500 g seed/ha	approx 7 oz seed/acre

¹ Precision-seed or thin plants to the recommended in-row spacing.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Apply up to 35 kg N/ha. If manure is used in the rotation, apply it at least 1 year before the rutabaga crop is grown.

Phosphorus

Test the soil to determine phosphorus requirements. Where soil test values are 61 mg P per L soil (ppm) or higher, rutabagas are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where soil test values are 181 mg K per L soil (ppm) or higher, rutabagas are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate prior to planting.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Boron

Water-core or brown heart, caused by boron deficiency, first appears in young, growing roots as firm, brownish, water-soaked patches. Severely affected rutabagas develop a soft, brown internal discolouration during storage.

Mix boron with preplant fertilizer applications. Apply boron-enriched fertilizer as uniformly as possible. Foliar applications of Solubor are often as effective as larger amounts applied to the soil. Make the first foliar application when the roots are about 1.5–2.5 cm (3/8–1 in.) in diameter. The second and third applications can be applied at 10- to 14-day intervals. See Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Do not combine pesticides with boron sprays unless the label specifies compatibility. Use caution when applying boron. Many rotational crops are sensitive to high levels of boron in the soil.

Table 9-84. Rutabaga Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI¹	Notes
PYTHIUM DAMPING-OFF						
phenylamides (group 4)	metalaxyl-M	Apron XL LS	20–40 mL/100 kg seed			One application as a seed treatment.
dithiocarbamate (group M3)	thiram	Thiram 75 WP	90 g/25 kg seed			Damping off and seedling blight.
MOSAIC VIRUS						
N/A	mineral oil	Superior Oil 70	11 L in 550–1,100 L of water	4.4 L in 50–100 gal of water	21	Do not apply mineral oil in direct sunlight. Aphid feeding deterrent only.
DOWNY MILDEW						
phosphonate (group U)	fosetyl-al	Aliette WDG	2.25–3.12 kg in minimum 100 L water	0.9–1.25 kg in minimum 10 gal water	7	Maximum 5 applications/yr. Spray at 7-day intervals as required. 12-hr re-entry interval.
POWDERY MILDEW						
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	224–336 g	3	Maximum 3 applications/yr. Do not use more than 2 applications before rotating to a different fungicide group. 3-day re-entry interval for hand thinning activities.
DMI (group 3)	propiconazole	Topas 250 E	400 mL in minimum 200 L water	160 mL in minimum 18 gal water	21	A second application may be made 20 days after the first.
		Mission 418 EC	240 mL in minimum 200 L water	96 mL in minimum 18 gal water	21	Make 2 applications/yr: the 1st application 50 days after planting and the 2nd application 20 days later.
inorganic (group M1)	sulphur	Microscopic Sulphur	6.8 kg in 675–1,125 L water	2.75 kg in 60–100 gal water	0	Maximum 5 applications/yr. This product is not compatible with Superior Oil. 24-hr re-entry interval.
RHIZOCTONIA						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/ 100 m of row	1.2–1.8 mL/ 100 ft of row	40	One application/yr. Applied in-furrow at planting or banded soon after emergence.

¹ PHI = Pre-Harvest Interval (days).

Integrated Pest Management

OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario*, provides a good summary of IPM for rutabagas in Ontario.

Diseases

DAMPING-OFF AND ROOT ROTS

See *Damping-Off and Root Rots* (*Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Penicillium*), on page 59, for more information. See Table 9-84, *Rutabaga Disease Control Recommendations*, this page.

BLACK ROT AND BLACK LEG

Identification: Seedlings infected with black rot usually die. Later infections cause stunted plants with yellow, wilting foliage. Leaf and stem veins and the vascular bundles under the skin of the root turn black. Root rots may also develop.

Seedlings infected with black leg may die or may simply lose their cotyledons. On mature plants, cankers develop on the root. Dry, sunken spots with dark borders develop in storage. Waxed roots rot rapidly.

Development: Rutabagas are susceptible to these diseases at the seedling stage, as mature plants and in storage.

Management Notes: Do not apply manure or compost containing rutabaga refuse or diseased rutabagas on land intended for rutabagas. Follow a 4–5-year rotation away from all brassica crops. The black leg pathogen can move with wind and water from adjacent fields. Control brassica weeds. Never store diseased rutabagas. Clean out and disinfect the storage area each spring. See *Storage Sanitation*, on page 50.

CLUBROOT

Identification: Galls develop on the taproot or secondary roots. Infected plants become stunted. Older

leaves may turn yellow and drop. Younger leaves wilt during the heat of the day.

Development: The clubroot pathogen prefers temperatures of 19°C–23°C and high soil moisture levels. This disease is more severe on acid soils.

Management Notes: Clubroot is the most serious disease affecting rutabagas. Use a long crop rotation (at least 5 years) with non-brassica crops to avoid infection. Avoid planting into infested fields. Maintain a soil pH of 7.2.

POWDERY MILDEW

Identification: White, powdery spots develop on the upper surface of older leaves. Leaves turn pale green to yellow and eventually die.

Development: Powdery mildew proliferates during periods of warm weather and low humidity. It requires some moisture (from heavy dews or intermittent rain) for initial infection.

Management Notes: The Laurentian variety is very susceptible to powdery mildew. Fungal spores can travel long distances by wind. Initiate control tactics at the first appearance of symptoms. See Table 9–84, *Rutabaga Disease Control Recommendations*, previous page.

TURNIP MOSAIC VIRUS (TUMV)

Identification: Older leaves turn yellow and drop prematurely. Leaves emerging after infection are stunted and wrinkled and show a yellow, mottled pattern. Roots become “goosenecked” and do not reach normal size.

Development: TuMV is spread by aphids. A rapid increase in infection usually begins in early July, when large numbers of winged aphids become active. Volunteer rutabagas and winter canola are the main overwintering sources of the virus.

Management Notes: Losses from turnip mosaic virus are especially heavy in plantings sown after mid-June. Applications of mineral oil (Superior 70 Oil) deter the feeding of virus-spreading aphids. See Table 9–84, *Rutabaga Disease Control Recommendations*, previous page. Aphid control does not completely prevent the spread of the virus.

For more information, see *Aphids*, on page 60, and *Viruses (General)*, on page 59.

For more information, see the OMAFRA Factsheets:

- *Turnip Mosaic Virus (TuMV) of Rutabaga*, Order No. 88-091
- *Fungal Diseases of Cruciferous Crops*, Order No. 85-043
- *Black Rot of Cruciferous Crops*, Order No. 02-025

Insects

CUTWORMS, APHIDS

For identification and management information on these common vegetable insects affecting rutabagas, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–85, *Rutabaga Insect Control Recommendations*, opposite page.

CABBAGE MAGGOT

Identification: The white, legless maggots feed and burrow in the roots, rendering them unmarketable.

Period of Activity: Cabbage maggots overwinter as pupae in the soil. There are three periods of maggot damage. The first generation is the most active and most damaging. It occurs from mid-May through June (flowering of yellow rocket). A second occurs in mid-July (flowering of day lilies) and a third in late August (flowering of goldenrod). These dates are approximate. Pest activity levels vary depending on regional temperatures and differences in soil type.

Thresholds: Monitoring programs for cabbage maggot adults can help with spray timing. A Growing Degree Day (GDD) model developed for cabbage maggot uses a base temperature of 6°C. First generation adults emerge between 314 and 398 GDD. Second generation adults emerge between 847 and 960 GDD. Third generation adults emerge between 1,446 and 1,604 GDD.

Management Notes: Follow a 3–4-year crop rotation. Do not grow early and late rutabagas in the same field or near winter canola, early broccoli, cabbage or cauliflower. Time control of root maggots to coincide with the egg-laying activity of each generation. See Table 9–85, *Rutabaga Insect Control Recommendations*, opposite page.

FLEA BEETLES

Identification: Small, shiny, black beetles feed on leaves and cotyledons, leaving a “shot-hole” appearance. They can also feed on the stem below the soil surface. Larvae feed on the roots.

Period of Activity: Rutabaga plants are most vulnerable at the seedling stage. Larval feeding on the root may reduce marketability.

Table 9–85. Rutabaga Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
CABBAGE ROOT MAGGOT						
Treatment at Planting						
organophosphate (group 1B)	chlorpyrifos	Lorsban 15 G	0.6–1 kg/ 1,000 m of row	0.18–0.3 kg/ 1,000 ft of row	30	24-hr re-entry interval.
Treatment After Planting						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	210 mL/ 1,000 m of row (in 125 L of water)	64 mL/ 1,000 ft of row (in 11 gal of water)	30	Apply on soil, 10 cm (4 in.) on each side of the plant, 10, 28, 49 and 70 days after seeding. Maximum 4 applications/yr. 24-hr re-entry interval.
FLEA BEETLES						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	123 mL	49 mL	21	12-hr re-entry interval. Apply before 8-leaf stage.
		UP-Cyde	200 mL	81 mL	21	
	permethrin	Pounce 384 EC	180 mL	72 mL		
		Ambush 500 EC	140 mL	56 mL		
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1.0 L	7	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2.0 L	0.8 L	45	Also control aphids. Maximum 2 applications/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	45	
LEAF-EATING CATERPILLARS						
spinosyn (group 5)	spinosad	Success 480 SC	182 mL	73 mL	3	Maximum 3 applications/yr. Maintain a spray pH of 6 or higher. 72-hr re-entry (hand-thinning).
		Entrust 80 W	109 g	44 g	3	
	spinetoram	Delegate WG	140–200 g	56–80 g	3	
chlorinated cyclodiene (group 1A)	endosulfan	Thiodan 4 EC	2.0 L	0.8 L	45	Also controls aphids. Maximum 2 applications/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	45	
CUTWORMS						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L in 200–400 L water	0.5–1.0 L in 20–40 gal water	30	May be used at the rate of 2.4 L/ha (1.0 L/ acre) as a preplanting treatment. Apply once at seedling stage (2–5 leaves), when damage first appears. 24-hr re-entry interval.
		Pyrinex 480 EC				

¹ PHI = Pre-Harvest Interval (days).**Thresholds:** None have been established.

Management Notes: Target controls at the adult beetle stage. There is no control for larvae established in roots. Begin applications as soon as beetles appear in the field. Beetles may migrate into the field over several weeks, resulting in the need for multiple applications. Insecticide drenches applied for root maggot control may also control flea beetles.

LEAF-EATING CATERpillars

Imported cabbageworm, diamondback moth and cabbage loopers can attack rutabagas. For more information, see *Imported Cabbageworm*, *Cabbage Looper*, *Diamondback Moth Caterpillar*, on page 91. Also see Table 9–85, *Rutabaga Insect Control Recommendations*, this page.

Before feeding rutabaga tops or trimmings to livestock, check all pesticide labels for restrictions.

See Table 9–85, *Rutabaga Insect Control Recommendations*, this page. To limit the development of resistance, alternate between insecticide groups.

Nematode Control

See *Nematodes*, on page 63, for control recommendations.

Harvest and Storage

Damaged and bruised rutabagas do not store well and rot quickly. To reduce losses from post-harvest diseases, change the water in the wash tank frequently or add fresh water continuously to keep water as clean as possible. Rinse with clean water and dry immediately. Trimming after washing also helps reduce storage rots. Use calcium hypochlorite (bleach) in the rinse water to reduce losses after waxing. See *Storage Sanitation*, on page 50.

Waxing

Rutabagas are normally hot-waxed just before being marketed. Waxing improves their appearance, keeps them clean, protects freshly trimmed surfaces from disease organisms and prevents undue moisture loss and shrinkage during the marketing period. Waxing is not recommended for rutabagas being held in storage.

Immerse clean, dry rutabagas for one second in a "rutabaga/turnip" wax at 126°C and then pack as desired for market. Temperatures must be kept low after waxing. Waxed rutabagas can spoil within a few days at room temperature. Rutabaga wax is available from the International Group Incorporated (IGI), 50 Salome Dr., Scarborough, Ontario, Tel. 416-293-4151. Ask for "turnip wax" — product code 2291.

Storage

Disease-free rutabagas will keep up to 6 months. Store at 0°C and a relative humidity of 90%–95%. Maintain adequate ventilation and air movement throughout the storage area. Clean the storage area thoroughly between crops.

For more information see Chapter 6, *Food Safety and Storage*, on page 45.

For more information, see the OMAFRA Factsheet, *Storing Rutabagas*, Order No. 80-001.

SPECIALTY VEGETABLES

Many of the specialty vegetables grown in Ontario are of Asian, Indian and Middle Eastern origin. These crops belong to a range of plant families that includes legumes, brassica crops and cucurbits. Pest management strategies developed for more traditional crops may be helpful in these crops, since they often have similar insect and disease complexes.

Nomenclature

Many of the crops of Asian origin have different names in different languages (Mandarin Chinese, Cantonese Chinese, Vietnamese, Korean or Japanese, for example). Table 9-86, *Specialty Vegetables*, next page, summarizes some of the Asian specialty vegetable crops grown in Ontario.

For more information, see the OMAFRA Factsheet, *Asian Vegetables Grown in Ontario*, Order No. 98-033.

Fertility

Because of the wide range of specialty crops, a single fertility recommendation cannot be made. However, a balanced fertility program based on a soil test can form the basis for good crop health. Experience from related crops will also be useful. See Chapter 1, *Vegetable Crop Fertility*, for more information on nitrogen, phosphorus, potassium and the micronutrients.

Integrated Pest Management

For more information, see these OMAFRA publications:

- OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario*.
- *Ontario Crop IPM*, Order No. AF141

Diseases

Many of the diseases affecting specialty crops are seed-borne. If possible, purchase certified, hot-water treated seed.

The following best management practices can help reduce disease problems:

- Use treated seed.
- Deep-plow crop residues into the soil.
- Eliminate cull piles.
- Follow a 3-4-yr rotation with unrelated crops.

- Remove weed hosts.
- Reduce overhead irrigation.
- Use only healthy transplants grown in clean plug trays and sanitized greenhouses.

COMMON DISEASES OF SPECIALTY VEGETABLES

Asian radish (lo bok, daikon, moo): Turnip mosaic virus, downy mildew, alternaria leaf blight

Nappa cabbage (siew choy, da bai cai, baechu): Turnip mosaic virus, downy mildew, soft rot, alternaria leaf spot, clubroot, pseudocercospora leaf spot

Bok choy, gai choy, yow choy, pak choy, gai lan, etc.: Turnip mosaic virus, downy mildew, soft rot, clubroot, pseudocercospora leaf spot, alternaria leaf blight

Cucurbits (fuzzy squash, bitter melon, winter melon): Powdery mildew, downy mildew, mosaic viruses, bacterial wilt, angular leaf spot, scab, anthracnose

For identification, management and chemical control options for several insects and diseases of specialty vegetables, see *Brassica Crops*, on page 82, and *Cucurbits*, on page 106.

Harvest and Storage

Most specialty vegetables reach maturity in 40-70 days (sometimes 90-100 days for late fall nappa cabbage or specialty melons) under good growing conditions. All specialty vegetables are hand-harvested. Most radish and melon types are washed before marketing. The leafy greens are packed directly into crates or boxes in the field.

Leafy greens are a very perishable product. Cooling immediately after harvest and topping with ice, can increase shelf life for up to 10-14 days. Optimal storage conditions are 0°C and a relative humidity of 95%-100%.

For more information see Chapter 6, *Food Safety and Storage*, on page 45.

The following OMAFRA Factsheets contain more information on pest management:

- *Insects, Disease and Disorders of Asian Vegetables*, Order No. 00-095
- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Turnip Mosaic Virus (TuMV) of Rutabaga*, Order No. 88-091
- *The Swede Midge - A Pest of Crucifer Crops*, Order No. 08-007

Table 9-86. Specialty Vegetables

English	Chinese ¹	Korean	Japanese	Vietnamese	Latin
Edible amaranth (callaloo, calalbo, tampala)	hinn choy (C), xian cai (M)	chambirum	hi yu na	rau den do	<i>Amaranth mangostanus</i> <i>A. gangeticus</i>
Asian water celery or Water dropwort	shui qin (M)	minari	seri	cang nuoc, rau can nuoc	<i>Oenanthe stolonifera</i>
Asparagus bean or Snake bean	dau guak (C), cai dow (M)	gin kong	sasage	dua-dua	<i>Vigna unguiculato</i> var. <i>sesquipedalis</i>
Bitter melon	fu gua (C), ku gua (M)	ssunoi	ni ga uri	muop dang, khoqua	<i>Momordica charantia</i>
Bitter melon leaves	fu gua yip			la khoquo	<i>Momordica charantia</i>
Burdock root	ngao pong (C)	uang	gobo		<i>Arctium lappa</i>
Chinese broccoli or Chinese kale	gai lan (C), jie lan (M)		kailaan	cai ro	<i>Brassica alboglabra</i>
Nappa cabbage or Chinese cabbage	siew choy (C), won bok (C), da bai cai (M), huan ya bai (M)	baechu	hakusai	cai bac thao, cai dai	<i>Brassica rapa</i> var. <i>pekinensis</i> group
Chinese chives	gow choy (C), jiu cai (M)	buchu	nira	he	<i>Allium tuberosum</i>
Chinese cucumber	wong gua (C), huang gua (M)	oi		dua leo	<i>Cucumis sativus</i> var. <i>sativus</i>
Big leaf mustard	dai gai choy (C), da jie cai (M)	gat	karashina	cai zanh	<i>Brassica juncea</i> var. <i>involutus</i> ; var. <i>foliosa</i>
Chinese okra or Sponge gourd	guang dong si gua, si gua		shokuyou hechima, hechima	muop khia, muop huong	<i>Luffa acutangula</i> , <i>Luffa aegyptica</i>
Chinese squash/pumpkin	nam gua (C), nan gua (M)	ho bak	kabocha	bi ro	<i>Cucurbita moschata</i>
Japanese pumpkin	yin du nan gua		seiyou-kabocha	bi	<i>Cucurbita maxima</i>
Chrysanthemum greens	tong hao cai (M), tong ho choy (C)	ssukgat	shungiku	tan o, cai cui	<i>Chrysanthemum coronarium</i>
Flowering edible rape	yow choy (C), you cai (M)	yuchaeip	aburana	cai ngot	<i>Brassica rapa</i> var. <i>oleifera</i>
Fuzzy squash	mao gua, jie gua (M), tsit gua (C)	ho bak	tohgan	bi chanh	<i>Benincasa hispida</i> var. <i>chieh-qua</i>
Edible mallow (melokhia)				rau day	<i>Corchorus olitorius</i>
Red/green mustards	gai choy (C), jie cai (M)	gat	karashina	cai xanh	<i>Brassica juncea</i> var. <i>rugosa</i> ; var. <i>crispifolia</i>
Malabar spinach	lo kwai (C), san choy (C), zi luo kui (M), lu luo (M)		tsuru-murasaki	mong to'i	<i>Basella alba</i> , <i>Basella rubra</i>
Flowering Chinese leaf cabbage	choy sum (C), cai xin (M)		saishin	cai ngot non	<i>Brassica rapa</i> var. <i>parachinensis</i>
Flat flowering Chinese leaf cabbage	nai yow choy (C)				<i>Brassica rapa</i> var. <i>narinosa</i>
Rosette Chinese leaf cabbage	tak choy (C), wu ta cai (M)		tatsoi	cai tua xai	<i>Brassica rapa</i> var. <i>rosularis</i>
Purple mint, beefsteak plant	zi su (C)	dulketip	shiso	tia to	<i>Perilla frutescens</i> , <i>Perilla crispa</i>
Asian radish	lo bok (C), luo bu (M)	moo	daikon	cu-cai	<i>Raphanus sativum</i> <i>Longipinnatus</i> group
Potherb mustard	shui cai (C)		kyona, mizuna		<i>Brassica juncea</i> var. <i>japonica</i>
Salad rocket (arugula)					<i>Eruca vesicaria</i>
Snow peas	ho lan dow	wando	saya endo		<i>Pisum sativum</i> var. <i>macrocarpon</i>
Snow pea shoots	dow miu (C), dou miao (M)	wandusun	tohbyo		<i>Pisum sativum</i> var. <i>macrocarpon</i>
Thick petiole white Chinese leaf cabbage	bok choy (C), bai cai (M)	bok choy	shakushina	cai thuong hai	<i>Brassica rapa</i> var. <i>chinensis</i>
Thin petiole white Chinese leaf cabbage	pak choy (C), xiao bai cai (M)	pak choy	shakushina, chingensai (green stem)	cai trang laon	<i>Brassica campestris rapa</i> var. <i>chinensis</i>
Water spinach	tung choy (C), kongxin cai (M)	kongshim- chae	kankon, asagaona, ensai	rau muong	<i>Ipomoea aquatica</i>
Winter melon	tung kwa (C), don gua (M)		tohgan	bao	<i>Benincasa hispida</i>

¹ C = Cantonese Chinese, M = Mandarin Chinese

SPINACH & SWISS CHARD

Production Requirements

Spinach production occurs mainly in the spring or fall. Under long days and warm-weather conditions, plants quickly bolt (produce flower stalks) and become unmarketable. Bolting susceptibility may also be variety specific. Plant early and over-wintered crops in sandy or sandy-loam soils for best results. The ideal pH range for spinach on mineral soils is 6.5–7.5. On muck soils, the target pH is 5.1–5.5.

Most spinach varieties are ready for harvest in 40–50 days after planting under good growing conditions. Early spring plantings may require 50–70 days.

Recommended rotational crops: brassica crops, cucurbits, lettuce

Do not rotate with: beets, spinach, rhubarb

Average Yields

Crop	per acre	per hectare
Processing spinach	10,000–12,000 lb	11,000–13,000 kg
Fresh-market spinach (24 bunches per carton)	400 cartons	1,000 cartons

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236.

Seeding and Spacing

Sow outside as soon as the soil is workable, in early spring through to early May. Plant from July 31 to August 31 for a fall crop. Do not sow seed in hot weather conditions, as bolting may occur. For over-wintered spinach, sow in September.

Seed will germinate readily at soil temperatures as low as 3°C–4°C. Optimum germination occurs at 10°C–16°C. At higher temperatures, there is a more rapid emergence but decreased percentage germination.

Table 9–87. Spinach Nitrogen Recommendations

Soil Type	Actual N kg/ha
Mineral Soils	
Preplant	55
Side-dress	55
Total	110
Muck Soils	
Preplant ¹	75

¹ On muck soils, if rainfall has been excessive, an additional 55 kg/ha may be side-dressed.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Broadcast and incorporate the recommended preplant nitrogen with all the required phosphate and potash. For early sown crops, apply the total nitrogen recommendation as a preplant application. See Table 9–87, *Spinach Nitrogen Recommendations*, this page.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, spinach plants grown on both muck and mineral soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, spinach plants grown on both muck and mineral soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, and Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

	Spinach		Swiss Chard	
Row spacing:	30 cm	12 in.	30 cm	12 in.
In-row spacing:	5–10 cm	2–4 in.	10–12 cm	4–5 in.
Rate:	12 kg/ha	11 lb/acre	12 kg/ha	11 lb/acre

Table 9-88. Spinach Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL-LS	metalaxyl-M	20-40 mL/ 100 kg seed	damping-off (<i>Pythium</i>)	For use in commercial seed-treatment plants only. Not for greenhouse-grown spinach.
Thiram 75 WP	thiram	90 g/ 25 kg seed	seed decay and damping-off	seed box treatment.

If phosphate and potash are required, apply and incorporate prior to planting.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Boron

Boron deficiencies on spinach and Swiss chard are not common but can occur during periods of hot, dry weather. Leaves become twisted with light spots developing on the petioles. Internal breakdown may occur in the roots. External cankers may also develop on the root surface.

See *Boron*, on page 18, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16. Use caution when applying boron. Many rotational crops are sensitive to high levels of boron in the soil.

Magnesium

A magnesium deficiency may occur on spinach. The usual symptoms are yellowing of older leaves, while the veins remain dark green. See *Magnesium* and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information, see *Damping-Off and Root Rots* (*Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Penicillium*), on page 59. Also see Table 9-88, *Spinach Seed Treatments*, this page.

DOWNY MILDEW

Identification: Infection usually begins on the mature, lower leaves and spreads inward. Chlorotic (yellowish) or pale-green areas appear on the upper surface of the leaves. Greyish-purple mould spores develop on the underside of the leaf.

Development: Infection can occur at any growth stage. Cool temperatures of 10°C–15°C and prolonged periods of leaf wetness, dew or fog support development. Downy mildew fungi survive for at least 1 year in the soil and 2 years in infected seed.

Management Notes: Resistant cultivars are available. Follow a 3-year rotation with non-host crops and plant into well-drained soils. Do not grow fall spinach crops in, or adjacent to, fields where an infected spring crop was grown. See Table 9-89, *Spinach and Swiss Chard Disease Control Recommendations*, opposite page.

FUSARIUM WILT

Identification: Fusarium wilt causes the outer leaves to wilt and turn yellow. Severe infections may progress to younger leaves. Light brown-to-black lesions develop on the roots, and the water-conducting vessels turn black.

Development: Moist soil conditions are required for initial root infection. Once established, the disease will progress quickly, especially if the soil becomes dry and the plants become stressed. Fusarium wilt is most severe at soil temperatures of 27°C.

Management Notes: In soils where this is a problem, do not seed spinach from May 31 to August 15. Some genetic tolerance may exist. Maintain a high soil pH; alkaline soils do not favour disease development.

SPINACH BLIGHT, CUCUMBER MOSAIC VIRUS, BEET MOSAIC VIRUS

Identification: Infected plants become stunted with progressive yellowing and mottling. Beet mosaic virus produces small spotting early in the infection period without the distortion of the leaves common to other viruses.

Development: Cucumber mosaic virus is usually transmitted by aphids.

Table 9–89. Spinach and Swiss Chard Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
DOWNY MILDEW						
Qol (group 11)	azoxystrobin	Quadris Flowable	1.125 L	455 mL	7	Spinach only. Begin applications prior to disease development.
carboxylic acid amides (group 40)	mandipropamid	Revus	400–600 mL	161–243 mL	1	Maximum 4 applications/yr. The use of a non-ionic adjuvant (0.125% v.v) is recommended.
strobilurin/anilid (group 7/11)	pyraclostrobin/boscalid	Prisine WG	1.6 kg	0.6 kg	0	Suppression only. Maximum 2 applications/yr. 24-hr re-entry interval. 9 days for hand harvesting and thinning.
WHITE RUST						
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	4–8 L	1.6–3.2 L	0	Suppression only. Begin applications when conditions become conducive for disease development. Repeat at 7–10 day intervals.

¹ PHI = Pre-Harvest Interval (days).

Management Notes: Virus-resistant cultivars are available. Control weeds in adjacent fencerows. Milkweed, ground cherry, pokeweed, chickweed and mother-wort are alternative hosts to the cucumber mosaic virus. Avoid growing spinach near other mosaic-susceptible vegetable crops. See *Viruses (General)*, on page 59.

Insects

APHIDS

For identification and management information on this common pest of vegetable crops, see *Aphids*, on page 60, and Table 9–90, *Spinach and Swiss Chard Insect Control Recommendations*, next page.

LEAFMINERS

The pea leafminer adult causes severe stippling (bronzing) damage to spinach and Swiss chard leaves. Mining of the leaves by pea leafminer larvae is not as common. For more information, see *Leafminers*, on page 80. Other species of leafminer create twisted mines underneath the leaf surface. See Table 9–90, *Spinach and Swiss Chard Insect Control Recommendations*, next page.

CABBAGE LOOPER

Cabbage looper causes sporadic damage in Ontario. The suggested threshold is 5%. For more information, see *Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar*, on page 91. See also Table 9–90, *Spinach and Swiss Chard Insect Control Recommendations*, next page.

For more information on spinach and Swiss chard IPM, see the following OMAFRA Factsheets:

- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Caterpillar Pests of Crucifer Crops*, Order No. 99-035
- *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053

Nematode Control

To avoid damage from sugarbeet cyst nematode, do not plant spinach following rhubarb, beets or spinach. (See *Nematodes*, on page 63.)

Harvest and Storage

Spinach is often harvested when it has five or six leaves. Higher yields result when plants have 10–12 leaves. Most of the Ontario crop is machine harvested. Spinach is usually washed before marketing.

Remove the field heat from spinach as soon as possible after harvest. Stored product may last for 10–14 days under good conditions. Store at 0°C and a relative humidity of 95%–100%.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

Table 9-90. Spinach and Swiss Chard Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
LEAFMINERS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	35 g	7	Maximum 5 applications/yr. Alternate applications with different insecticide groups. 12-hr re-entry interval.
chitin biosynthesis inhibitor (group 17)	cyromazine	Citation 75 WP	188 g in 200 L water	76 g in 18 gal water	7	Maximum 5 applications/yr. 12-hr re-entry interval.
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.4 kg	10	Spinach only.
		Diazinon 500 E	1.1 L	0.4 L	10	
	malathion	Malathion 25 W	5.5-7.0 kg	2.2-2.8 kg	7	
APHIDS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56-86 g	23-35 g	7	Maximum 5 applications/yr. Alternate applications with different insecticide groups. 12-hr re-entry interval.
tetrone and tetramic acid derivatives (group 23)	spirotetramat	Movento 240 SC	220-365 mL	89-148 mL	3	Most effective on young stages. Has slow activity; control may not be apparent for 2-3 weeks. 12-hr re-entry interval.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	Spinach only. Maximum 1 application/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.4 kg	10	Spinach only. Control of aphids with diazinon has been inconsistent in many areas.
		Diazinon 500 E	1.1 L	0.4 L		
		Diazinon 50 W	1.1 kg	0.4 kg	14	
		Diazinon 500 E	1.1 L	0.4 L		
	dimethoate	Cygon 480	0.7 L	283 mL	7	Swiss chard only. Maximum 2 applications/yr.
		Lagon 480				
	naled	Dibrom	1.1-1.65 L	0.4-0.67 L	4	Control of aphids with naled has been inconsistent in many areas. 48-hr re-entry interval.
CABBAGE LOOPER						
biological (group 11)	<i>Bacillus thuringiensis</i>	Thuricide HPC	2.0-4.25 L	0.8-1.72 L	0	Spinach only.
		Dipel 2 XDF	275-550 g	111-223 g	0	
spinosyn (group 5)	spinosad	Success 480 SC	182 mL	74 mL	1	Maximum 3 applications/yr. Maintain a spray pH of 6 or higher.
		Entrust 80 W	109 g	44 g	1	
	spinetoram	Delegate WG	140-200 g	57-81 g	1	Maximum 3 applications/yr.
diamides (group 28)	chlorantraniliprole	Coragen	250 mL	101 mL	1	Maximum of 4 applications/yr.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	Spinach only. Maximum 1 application/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	naled	Dibrom	1.1-1.65 L	0.4-0.7 L	4	Spinach only. 48-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).

SUGARBEETS

SUGARBEETS

Production Requirements

Sugarbeets can be grown on a wide range of soil types. It is important to have good surface and subsurface drainage. Sugarbeets will perform best at a pH of 6.5–7.2. Manganese deficiency may become a problem at pH levels above 7.2.

Plant sugarbeets as early as possible for maximum yield potential. Planting can begin in late March if soil and weather conditions are suitable. Early harvest starts in late September, while main harvest runs from mid-October into November, once temperatures are suitable for building storage piles.

Recommended rotational crops: beans, cereal crops, corn, cucurbits, eggplant, peas, peppers, potatoes, soybeans, tomatoes

Do not rotate with: table beets, brassica crops

Average Yields

Crop	per acre	per hectare
Sugarbeets with sugar levels of 17%–19%	21–25 tons	47–55 tonnes

Cultivars

Follow processor's requirements.

Soil pH

Soil pH can have a significant impact on the breakdown of several commonly used field crop herbicides.

Carryover of these herbicides will severely injure sugarbeets. It takes time after the application of lime for the pH to fully adjust. Allow for sufficient time for herbicide breakdown after the pH adjustment. Even where the average pH of a field is suitable, areas of low or high pH may still exist.

imazethapyr (Pursuit, Clean Sweep, Conquest, Valor)	degrades very slowly at pH less than 6.0–6.5
flumetsulam (Broadstrike Dual Magnum) cloransulam (First Rate)	breaks down very slowly below a pH of 6, increased activity above a pH of 7.8
chlorimuron-ethyl (Classic)	degradation stops at a pH greater than 7

Table 9–91. Sugarbeet In-Row Spacing

Expected % Emergence ¹	Seed spacing needed to achieve:			
	180 sugarbeets		150 sugarbeets	
	per 30 m (100 ft) of row			
	cm	in.	cm	in.
40	6.8	2.7	8.1	3.2
50	8.4	3.3	10.2	4.0
60	10.2	4.0	12.2	4.8
70	11.9	4.7	14.2	5.6
80	13.5	5.3	16.3	6.4

¹ Normal emergence is approximately 60% in our growing areas. Aim for a minimum emergence of 180 sugarbeets/30 m in 71–76-cm rows and 150 sugarbeets/30 m in 51–56-cm rows.

Seeding and Spacing

The minimum germination temperature for sugarbeets is 4.5°C. Plant enough seed to give an emerged stand of 150–180 sugarbeets per 30 m of row. Adjust the seeding rate according to the row width. Aim for the high end of the range in 71–76-cm rows and the lower end of the range for 56-cm rows.

See Table 9–91, *Sugarbeet In-Row Spacing*, this page. These spacings will consistently produce more recoverable sugar per hectare than lower stands. The use of coated and primed seed improves plant emergence.

Proper planter set-up and maintenance are extremely important for successful establishment of the sugarbeet stand. Good seedbed preparation is also important for achieving early seeding dates, rapid seedling emergence and a uniformly spaced stand. Deep or excessive spring tillage reduces soil moisture and increases crusting, impacting sugarbeet emergence. Planting depth will vary with soil types and moisture conditions. A depth of 2.5 cm is generally satisfactory.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Table 9–92. Sugarbeet Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL/ 100 kg seed	damping-off (<i>Pythium</i>)	For use in seed-treatment plants only.
Apron FL	metalaxyl	93 mL/ 100 kg seed	pythium seed rot, seedling blight	
Allegiance FL	metalaxyl	93 mL/ 100 kg seed	pythium seed rot, seedling blight	
Maxim 480 FS	fludioxonil	5.2–10.4 mL/ 100 kg seed	seed- and soil-borne diseases (<i>Fusarium</i> , <i>Rhizoctonia</i> , <i>Aspergillus</i> , <i>Penicillium</i>)	For import use only. Not for domestic commercial or on-farm seed treatment.
Thiram 75 WP	thiram	90 g/ 25 kg seed	seed decay, seedling blight, damping-off	Do not graze or feed treated clippings to livestock.

After field corn, use 120–150 kg N/ha. Reduce nitrogen application to 100–130 kg/ha when following other crops. Excess nitrogen will not increase sugarbeet yield but will decrease sugar content and clear juice purity.

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 51 mg P per L soil (ppm) or higher, sugarbeets are unlikely to respond to additional phosphate applications. For soils testing lower than 51 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Soil tests are required to determine potassium requirements. Where the soil test values are 151 mg K per L soil (ppm) or higher, sugarbeets are unlikely to respond to additional potash applications. For soils testing lower than 151 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Excessive application of potassium will lead to luxury consumption by the sugarbeet plant. This has a negative effect on clear juice purity and sugar recovery.

Starter Fertilizer

Fields with high soil-test levels of phosphorus and potassium do not generally require starter fertilizer. Where starter is required, place it in a band at least 5 cm to the side and 5 cm below the seed to avoid seedling injury. See *Starter Fertilizers for Vegetable Crops*, on page 6.

Manganese

Manganese deficiencies are more common on heavier textured soils with high pH and high soil organic matter levels. Deficient plants show marked yellowing between the leaf veins; the veins themselves remain green. If soybeans regularly exhibit manganese

deficiencies in the field, then manganese deficiency may also occur in sugarbeets. To correct a deficiency, spray with manganese sulfate. See *Manganese*, on page 18, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

Varieties recommended by the processor have considerable tolerance to seedling diseases and damping-off. See Table 9–92, *Sugarbeet Seed Treatments*, this page, and *Damping-Off and Root Rots* (*Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Penicillium*), on page 59.

CERCOSPORA LEAF SPOT

Identification: Numerous small, circular lesions develop on the leaves. Small black dots in the centre of the lesions can be seen with a hand lens. *Cercospora* leaf spot can lead to defoliation and reductions in both yield and sugar content.

Development: *Cercospora* leaf spot is most active from mid-July through early September. Air temperatures above 24°C with extended periods of leaf wetness due to rain, dew, or fog are favourable for disease development.

Thresholds: Use BEETcast to determine optimum fungicide timing. See *BEETcast*, opposite page. If BEETcast is unavailable, begin the fungicide program as soon as leaf symptoms appear.

Table 9-93. Sugarbeet Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
CERCOSPORA LEAFSPOT						
benzimidazole (group 1)	thiophanate- methyl	Senator 70WP	420–560 g	170–227 g	21	Systemic. Always rotate with a different fungicide group. Follow an IPM and resistance management strategy. Maximum 2 applications/yr. For sugarbeets grown for export use only. Do not feed any part of treated plants to livestock.
Qol (group 11)	pyraclostrobin	Headline EC	670–900 mL	271–364 mL	7	Systemic. Use high rate when disease pressure is high. Maximum 4 applications/yr. Always rotate with a different fungicide group. 12-hr re-entry interval.
dithiocarbamate (group M2)	mancozeb	Manzate Pro-Stick	2.25 kg	0.9 kg	21	Apply every 7–10 days.
		Penncozeb 80 WP				Do not use treated beet tops for feed. 24-hr re-entry interval.
	metiram	Polyram DF	2.25 kg	0.9 kg	21	Apply at 7–10-day intervals. Do not use treated beet tops for feed.
inorganic (group M1)	copper hydroxide	Parasol WP	2.25–4.5 kg	0.9–1.8 kg	1	Apply at 10–14-day intervals once disease is detected. Add suitable non-herbicidal agricultural oil at 5.5 L/ha.
RHIZOCTONIA ROOT AND CROWN ROT						
Qol (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/ 100 m of row	1.2–1.8 mL/ 100 ft of row	100	In-furrow application. Make only 1 application/yr.
			0.5–1.1 L	0.2–0.4 L	100	Banded over the row before the 6th-leaf stage. Do not apply over the row if Quadris has previously been applied in-furrow.
POWDERY MILDEW						
Qol (group 11)	pyraclostrobin	Headline EC	670–900 mL	271–364 mL	7	Use high rate when disease pressure is high. Maximum 4 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 12-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).

Management Notes: Sugarbeet varieties have varying levels of leaf spot tolerance.

The currently registered cercospora fungicides must be managed responsibly to avoid the development of fungicide resistance. Start the fungicide spray program with a systemic product such as Headline. Follow BEETcast to time this and subsequent applications correctly.

Switch to another systemic fungicide group for the second application. Further applications, if required, can again include a systemic fungicide. Avoid making sequential applications of Headline EC or Senator 70 WP. If possible, incorporate a dithiocarbamate fungicide (e.g., Dithane, Penncozeb, Manzate, Polyram) into the program. Follow a shorter Disease Severity Value (DSV) spray interval when using the dithiocarbamates.

See Table 9-93, *Sugarbeet Disease Control Recommendations*, this page.

Fungicide applications can cease once daily maximum temperatures drop below 15°C.

BEETcast

The BEETcast program uses temperature and leaf wetness measurements to schedule preventative fungicide applications, before the damaging disease symptoms are visible. BEETcast calculates a daily Disease Severity Value (DSV) for each location. A zero means conditions were not favourable for disease development, due to cool temperatures or dry leaves. Favourable conditions, due to warm temperatures and periods of leaf wetness, are given a rating of 1 to 4. Spray applications are made when the accumulated daily DSVs reach a target number. BEETcast DSVs are available from Weather Innovations Incorporated, with support from the Michigan Sugar Company. For more information, contact Weather Innovations Incorporated at 519-352-5334 or visit their website at www.weatherinnovations.com.

Table 9–94. Sugarbeet Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
WIREWORM						
organophosphate (group 1B)	terbufos	Counter 15 G	45 g/ 100 m of row	13.7 g/ 100 ft of row	120–150	Apply in-furrow at planting. Do not place in direct contact with seed. Rates based on minimum 50 cm (20 in.) spacing. 48-hr re-entry interval.
CUTWORMS						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1.0 L	90	24-hr re-entry interval.
pyrethroid (group 3)	permethrin	Ambush 500 EC	140–300 mL	57–121 mL	1	Apply in the late evening or at night.
		Perm-UP	180–390 mL	73–158 mL	1	Do not disturb the soil for 5 days after application. Use high rates on dry or muck soils or on large larvae. 12-hr re-entry interval.
FLEA BEETLES, LEAFHOPPERS, SPIDER MITE						
organophosphate (group 1B)	malathion	Malathion 500 E	1.1 L	0.4 L	0	Flea beetles. Apply at the 3–5-leaf stage when insects or damage first appears.
	naled	Dibrom	2.2 L	0.9 L	5	Red spider mites, leafhoppers. 48-hr re-entry interval.

¹ PHI = Pre-harvest Interval (days).**RHIZOCTONIA ROOT AND CROWN ROT**

Identification: Rhizoctonia initially attacks the base of the plant, causing wilting and the eventual death of the foliage. It progresses to rotting of the crown and root.

Development: Rhizoctonia root and crown rot is a warm weather disease. It becomes active late in the season, at temperatures of 25°C–33°C. Fields considered at high risk for *Rhizoctonia* infections include those with a history of the disease or fields in which a host crop was grown the previous year. Stressful growing conditions will also make plants more susceptible to infections.

Management Notes: Avoid throwing soil onto sugarbeet crowns during cultivation. Rotate with corn or small grains. *Rhizoctonia*-resistant varieties are available. Do not dump sugarbeet tare dirt onto fields scheduled for sugarbeets the following year. Fungicides must be applied early in the season to be effective. See Table 9–93, *Sugarbeet Disease Control Recommendations*, previous page.

POWDERY MILDEW

This pathogen does not overwinter in our growing area, but can blow in from western North America. It is not generally of economic concern, but heavy infestations do occur sporadically. See Table 9–93, *Sugarbeet Disease Control Recommendations*, previous page.

Insects**CUTWORMS, WIREWORMS**

For identification and management information on these common vegetable insects affecting sugarbeets, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9–94, *Sugarbeet Insect Control Recommendations*, this page.

FLEA BEETLES AND SPRINGTAILS

Identification: Flea beetles are tiny, dark-coloured beetles. They eat small, round holes in the leaves. Springtails are small insects that cause scraping or scarring on leaves and roots. They are sometimes confused with flea beetles.

Period of Activity: Early in the season.

Thresholds: These pests do not usually cause economic injury in Ontario. Flea beetle control may be necessary if 25% or more of seedlings show damage.

Management Notes: See Table 9–94, *Sugarbeet Insect Control Recommendations*, this page.

ROOT APHIDS

Root aphids are a localized but serious pest in some years. Inspect roots for woolly spots, waxy exudate or the presence of aphids. Certain sugarbeet varieties have tolerance to this pest.

LEAFMINERS, LEAFHOPPERS, SPIDER MITES

These pests are often present in Ontario sugarbeet fields. However, they do not usually cause economic damage. If populations build to damaging levels, see Table 9-94, *Sugarbeet Insect Control Recommendations*, opposite page.

Lamb's-quarters is an alternate host for leafminers. Good weed control can reduce infestations.

Note: As the Ontario sugarbeet crop is processed entirely in the U.S., all products used must have both Canadian and U.S. registrations on sugarbeets. The processor may have specific restrictions and recommendations. Check with a processing company representative before spraying.

Sugarbeet Cyst Nematode

Rotation to non-host crops for 4–5 years will significantly reduce populations of this nematode. Avoid rotation with other host crops, including table beets, cruciferous crops and rhubarb. Varieties with tolerance to sugar beet cyst nematode (SBCN) are available. SBCN is an expanding problem in Michigan but has not been confirmed in the Ontario growing area since the 1960s. (See *Nematodes*, on page 63.)

Harvest and Storage

Handle sugarbeets as gently as possible to minimize breakage and bruising. Adjust flails or knives to remove all green leaf material from the crowns. Top only what can be harvested the same day. Topped beets will freeze in the field much more quickly than beets with tops. When sugarbeet crowns are frosted or frozen in the field, delay harvest until the tissue has had a chance to thaw and stabilize. Damaged, poorly topped, or freeze-damaged beets cause storage problems in the piles.

SWEET CORN

Production Requirements

Sweet corn is well adapted to a wide range of growing areas. Sweet corn is sensitive to cold soils and to frost. It performs best under warm growing conditions. Early-season production is suited to sandy-loam soils. Later plantings benefit from the higher moisture-holding capacity of silt-loam and clay-loam soils. The target pH is 5.6–6.

Sweet corn ripens in 60–100 days, depending on the variety. Fresh-market sweet corn is usually picked 21 days after 50% silk. Processing fields are harvested slightly later.

Recommended rotational crops: beans, peas, cucurbits, tomatoes, peppers, brassicas and wheat

Do not rotate with: corn (sweet, seed or field)

Average Yields

Crop	per acre	per hectare
Processing	6–8 tons	13–18 tonnes
Fresh market	1,000 doz (200 bags)	2,500 doz (500 bags)

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236. Processing sweet corn growers must grow varieties specified by the processor.

Seeding and Spacing

Early-season fresh market varieties:	40,000–45,000 plants/ha (16,000–18,000 plants/acre)
Main season and processing varieties:	45,000–55,000 plants/ha (18,000–22,000 plants/acre)

Row spacing:	75–90 cm	30–36 in.
In-row spacing:	20–25 cm	8–10 in.
Rate:	11–17 kg seed/ha	10–15 lb/acre
Depth:	4–7.5 cm	1.5–3 in.
(Always plant into moisture.)		

Soil Temperature

The minimum soil temperature needed for germination depends on the cultivar and its gene

type. Crops planted into cold soils suffer from delayed, uneven emergence. Planting into cold soils also increases the risk of losses to early-season pests, such as three-leaf dieback, seedcorn maggots and wireworms.

Gene Type	Minimum Soil Temperature
Normal (su)	13°C
Sugar-enhanced (se)	16°C
Supersweet (sh2)	18°C

Isolation

All sweet corn must be isolated from field corn. Supersweet (sh2) varieties must be separated from both normal (su) and sugar enhanced (se) varieties. Cross-pollination will turn sh2 kernels starchy. If se varieties are pollinated with su pollen, they will revert back to normal sugar levels.

Yellow is the dominant colour gene. Isolation of white varieties is necessary to avoid colour contamination. Bicolour cobs pollinated with pollen for yellow varieties have a lower proportion of white kernels. Isolate indian corn from all types of sweet corn. Cross-pollination between these two types causes black kernels to appear in the sweet corn cobs.

Separate incompatible varieties by at least 100 m or schedule the plantings so that pollen-shed is at least 2–3 weeks apart.

Fertility Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 10, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

On all soils, 90 kg N/ha is recommended.

Side-dress applications are an effective method of delivering nitrogen to sweet corn. Early plantings benefit from the use of a starter fertilizer. Apply the starter-fertilizer in a band 5 cm to the side and 5 cm below the seed. To avoid fertilizer injury, do not exceed the maximum banded application rates listed in Table 9–95, *Maximum Banded Application Rates for Sweet Corn*, opposite page.

Table 9-95. Maximum Banded Application Rates for Sweet Corn

Fertilizer	Maximum Banded Application Rates ¹ kg/ha
Nitrogen	75
Nitrogen + potash	75 + 45
Urea	40
Urea + potash	40 + 40

¹ Based on 75-cm rows.

Alternatively, pop-up fertilizer may be applied in the furrow directly with the seed:

- Do not use more than 9 kg nitrogen-plus-potash/ha.
- Do not place urea with the seed.

Avoid "pop-up" starter fertilizers that use urea as the nitrogen source. If the N component is more than half as much as the P component, the starter may contain urea.

Side-dress the remainder of the nitrogen before the corn is 30 cm high.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 31 mg P per L soil (ppm) or higher, sweet corn fields are unlikely to respond to additional phosphate applications. For soils testing lower than 31 mg P per L soil (ppm), see Table 1-10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Phosphate is best applied in a band at the time of planting. Depending on the soil test rating, additional broadcast P applications may or may not be necessary.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 121 mg K per L soil (ppm) or higher, sweet corn fields are unlikely to respond to additional potash applications. For soils testing lower than 121 mg K per L soil (ppm), see Table 1-12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, on page 17.

Zinc

Zinc deficiencies occasionally occur on coarse sandy-loam soils with low organic matter. Plants develop pale

yellow bands between the leaf veins, particularly near the leaf axils of the new growth. Soil tests are useful for identifying potential deficiencies. Apply zinc mixed in the fertilizer or as a banded application. See *Zinc*, on page 19, and Table 1-13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

Diseases

SEED DECAY, DAMPING-OFF AND THREE-LEAF DIEBACK

Symptoms occur either before or shortly after emergence. Under severe conditions, the infected seed fails to germinate. More commonly, the infection occurs in the developing roots, causing the young plants to suddenly die off. These infections are caused by several fungi, including *Penicillium*, *Pythium*, *Rhizoctonia* and *Fusarium*. *Penicillium* occurs as a seed contaminant, while the other organisms are common to most agricultural soils.

Seeds planted into cool, wet soils and sh2 varieties are most susceptible.

To prevent these diseases, use one of the fungicide seed treatments listed in Table 9-96, *Sweet Corn Seed Treatments*, next page.

Seed treatments usually provide only 2 weeks of protection to the seed. Planting into suitably warm soils and ensuring rapid germination is the best protection against these diseases. For more information, see *Damping-Off and Root Rots* (*Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Penicillium*), on page 59.

STEWART'S WILT

Identification: Plants infected before the 5-leaf stage become stunted, wilt and die. Later infections cause pale green or yellow stripes, running parallel to the leaf veins. Late damage is easily confused with magnesium deficiency. Wilt-infected plants exhibit brown, mushy tissue inside the stem.

Development: Stewart's wilt is transmitted by the corn flea beetle. Yield losses are most significant when susceptible varieties are infected before the 7-leaf stage. On susceptible varieties, losses at this stage may range from 40%–100%.

Table 9–96. Sweet Corn Seed Treatments

Active Ingredient(s)	Trade Name	Insects				Seedling Blights				Notes
		Seedcorn Maggots	Wireworm	White Grubs	Flea Beetles	Penicillium	Pythium	Fusarium	Rhizoctonia	
thiamethoxam + fludioxonil + metalaxyl-M + azoxystrobin	Cruiser 5 FS + Maxim 480FS + Apron XL LS + Dynasty 100FS	✓	✓	✓	✓	✓	✓	✓	✓	For use in commercial seed-treatment plants only. See the product labels for rates. Request the high rate for wireworm control and where the field has a history of pest pressure.
thiamethoxam + azoxystrobin + fludioxonil	Cruiser 5 FS + Dynasty 100FS + Maxim XL	✓	✓	✓	✓	✓	✓	✓	✓	
diazinon/captan/thiothianate-methyl	DCT	✓				✓	✓	✓	✓	Seed box treatment. Use 125 g/25 kg of seed.
diazinon/captan	Agrox B-2	✓					✓	✓	✓	Seed box treatment. Use 85 g/25 kg of seed. Do not use on seed previously treated with an insecticide. Use within 1 month of treatment.
	Agrox CD	✓					✓	✓	✓	Seed box treatment. Use 50 g/25 kg of seed. Do not use on seed previously treated with an insecticide. Use on seed previously treated with captan or thiram.
difenoconazole/metalaxyl-M	Dividend XL RTA					✓	✓	✓	✓	Use 325 mL per 100 kg of seed. Do not graze or feed to livestock within 60 days of planting.
metalaxyl	Apron FL						✓			For use in commercial seed-treatment plants only. See the product labels for rates.
	Alliance FL						✓			
metalaxyl-M + fludioxonil	Apron XL LS + Maxim 480 FS					✓	✓	✓	✓	For use in commercial seed-treatment plants only. See the product labels for rates.
azoxystrobin + fludioxonil	Dynasty 100FS + Maxim XL					✓	✓	✓	✓	For use in commercial seed-treatment plants only. See the product labels for rates.
thiram	Thiram 75 WP						✓	✓	✓	Seed box treatment. Use 55 g/25 kg of seed.
imidacloprid	Gaucho 480 FL		✓		✓					For use in commercial seed-treatment plants only. See product label for rates. Request the high rate for flea beetles. Carry-over of Gaucho-treated seed is not recommended.
clothianidin	Poncho 600	✓	✓	✓	✓					For use in commercial seed-treatment plants only. See product label for rates. Will also control corn rootworm. One-year plant-back restrictions for leafy, root and tuber vegetables.
thiamethoxam	Cruiser 5FS	✓	✓	✓	✓					For use in commercial seed-treatment plants only. See product label for rates. Request the high rate for wireworm.

✓ = registered pest

Management Notes: Mild winters favour flea beetle survival and increase the risk of problems the following season. There is no control for this disease. Many varieties have excellent resistance to Stewart's wilt. Corn flea beetle control may help prevent the spread of this disease. See *Corn Flea Beetle*, on page 197, for more information.

RUST

Identification: Reddish-brown (rusty) pustules develop on the upper leaf surface. The size of each lesion ranges from 1–3 mm. Older pustules turn blackish-brown.

Development: Rust infection requires cool weather (16°C–23°C) and 3–6 hours of leaf wetness. Heavy

overnight dews favour development. The rust fungi does not overwinter in Ontario. Epidemics arise from spores blown in from the southern U.S. and Mexico.

Thresholds: Prior to silking, plants with more than 6 pustules per leaf will benefit from a fungicide application.

Management Notes: There is a wide range of rust resistance in sweet corn cultivars. Rust infections occurring after silk emergence are unlikely to result in yield losses. See Table 9–97, *Sweet Corn Disease and Insect Control Recommendations*, opposite page.

Table 9-97. Sweet Corn Disease and Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
RUST, NORTHERN CORN LEAF BLIGHT						
DMI (group 3)	propiconazole	Tilt 250 E	500 mL	202 mL	14	Aerial application permitted. Under severe disease pressure, make second application in 14 days. May be tank-mixed with Matador or Ripcord insecticides.
		Bumper 418 EC	300 mL	121 mL	14	
QoI (group 11)	pyraclostrobin	Headline EC	400–600 mL	162–243 mL	7	Rust only. Maximum 2 applications/yr. 12-hr re-entry interval.
	azoxystrobin	Quadris Flowable	453 mL in min. 200 L water	183 mL in min. 20 gal water	7	Maximum 2 applications/yr. Aerial application permitted.
chloronitrile (group M5)	chlorothalonil	Bravo 500	3.2 L	1.3 L	14	Rust only. Maximum 2 applications/yr. 48-hr re-entry interval.
CORN ROOTWORM						
pyrethroid (group 3)	tefluthrin	Force 3.0 G	37.5 g / 100 m of row ²	11.4 g / 100 ft of row ²		Apply in-furrow at planting.
CUTWORMS³						
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83 mL	34 mL	–	Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application. 24-hr re-entry interval.
		Silencer 120 EC				
	cypermethrin	Ripcord 400 EC	175 mL	71 mL	21	Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application.
	permethrin	Pounce 384 EC	180–390 mL	73–158 mL	–	Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application. Use high rate on large larvae, dry soils or muck soils.
Ambush 500 EC		140–300 mL	57–121 mL	–		
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1 L	70	Apply during 2–5 leaf stage in 200–400 L water/ ha (18–36 gal/acre). 24-hr re-entry interval.
		Pyrinex 480 EC				
SLUGS						
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Use high rates on severe infestations.

¹ PHI = Pre-Harvest Interval (days).² 75-cm row-spacing requires 5 kg/ha (2 kg/acre).³ Cutworm treatments are most effective if applied in the early evening or at night when cutworms are most active.**NORTHERN CORN LEAF BLIGHT**

Identification: Long, elliptical greyish-green or tan streaks (approximately 2–15 cm in length) develop on the lower leaves. As the disease progresses, the lesions spread to the upper leaves, forming large blighted or “burned” areas.

Development: Northern corn leaf blight is found during warm, wet growing conditions. It often first appears at the time of silking or later.

Thresholds: None have been established. Fungicides are most effective when applied at the first signs of the disease.

Management Notes: Crop rotation and tillage will reduce inoculum in surface residues. In reduced tillage systems, follow a good crop rotation and select resistant varieties. See Table 9-97, *Sweet Corn Disease and Insect Control Recommendations*, this page.

Insects**SEEDCORN MAGGOTS, WIREWORMS, CUTWORMS, APHIDS, SLUGS**

For identification and management information on these common vegetable insects affecting sweetcorn, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, Table 9-96, *Sweet Corn Seed Treatments*, opposite page, and Table 9-97, *Sweet Corn Disease and Insect Control Recommendations*, this page.

CORN ROOTWORM

Corn rootworm adults lay their eggs in the fall in corn fields. The following spring, emerging larvae feed on corn roots. They weaken the root system, often causing lodging (or goosenecking). Crop rotation will almost always control corn rootworm populations; however, a new variant of the corn rootworm is present in Ontario. This variant lays its eggs in soybean crops. Additional control may be necessary if this variant is present in fields rotated solely with soybeans. See Table 9-96, *Sweet Corn*

Soil Treatments, on page 194, and Table 9-97, *Sweet Corn Disease and Insect Control Recommendations*, previous page.

Adult beetles occasionally feed on corn silks in late July–early August. Populations are usually kept under control by corn borer and earworm sprays. Severe feeding may result in poor kernel set.

EUROPEAN CORN BORER

Identification: Full-grown corn borer larvae are 2.5 cm in length. They are greasy white in colour, with a dark head and spots on each segment. The eggs are shiny, white and laid in clusters of 30 that resemble fish scales. Corn borer larvae feed briefly on the leaves but soon tunnel into the protection of the stalk. As the crop matures, borers move from the stalk into the ear.

Period of Activity: Borers overwinter as pupae in corn stubble. Southwestern Ontario experiences two generations per year (bivoltine). Usually, the first-generation adults emerge in mid-June, and the population peaks in mid-July. Second-generation populations peak in August.

In the rest of the province, single-generation (univoltine) corn borers usually emerge in late June or early July. Populations peak in late July to early August.

Many areas within Southwestern Ontario (Lambton, Middlesex, Oxford, Brant, Norfolk and Niagara) have an overlap of the bivoltine and univoltine corn borer populations. These areas experience a sustained peak flight for much of July and August.

Sweet corn is susceptible to corn borer from the late-whorl stage (12–14 leaves) until harvest.

Thresholds: 5% feeding injury or the presence of eggs warrants an insecticide application.

Management Notes: Begin monitoring at the mid-whorl stage. If monitoring indicates a need, apply the first spray at tassel emergence. Direct the sprays down into the whorl and maintain good spray coverage of the leaves, tassels and ears. Target the small larvae before they enter the protection of the stalk or ears. Second-generation larvae often move quickly towards the ear.

There is a very low tolerance for insect damage in the fresh-market. Applications at 5–7-day intervals usually give satisfactory control. See Table 9-99, *Sweet Corn – European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations*, opposite page.

Table 9-98. Corn Earworm Spray Intervals

Moths/trap per week	Spray Intervals	
	below 27°C ¹	above 27°C ¹
1–6	5–7 days	5–7 days
7–90	5 days	4 days
More than 90	4 days	3 days

¹ Daily maximum temperature.

CORN EARWORM

Identification: Earworm larvae range in colour from yellowish, to green or brown. They have a fine double stripe running down their backs. The larvae are slightly larger than the European corn borer. Female earworm moths lay their eggs on corn silk. The larvae are usually found in the top third of the ear.

Period of Activity: Corn earworm do not overwinter in Ontario. They move from the U.S. and Mexico on tradewinds. In Southwestern Ontario, adult moths usually appear in mid-to-late July, or earlier, depending on the season. In eastern and northern areas, arrival occurs in mid-to-late August. In cooler years, these areas may not experience corn earworm at all.

Earworm activity is highest in hot weather conditions. Peak flights often occur immediately after severe thunderstorms.

Thresholds: Use pheromone traps to monitor corn earworm populations. Make insecticide applications according to the number of moths caught per week and the day-time temperatures. See Table 9-98, *Corn Earworm Spray Intervals*, this page.

Management Notes: Sweet corn is susceptible to corn earworm damage while the silks are green. Good spray coverage of the rapidly growing silks is important. Pyrethroid sprays break down quickly under high temperatures. Under these conditions, more frequent spray applications are required. See Table 9-99, *Sweet Corn – European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations*, opposite page.

Transgenic varieties (Bt Sweet Corn) have complete resistance to corn borers and partial resistance to earworms and fall armyworms. Insecticides may be needed for other pests if pressure is high. Check with your seed company representative for availability and planting restrictions.

Table 9-99. Sweet Corn - European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
EUROPEAN CORN BORER AND CORN EARWORM						
pyrethroid ² (group 3)	lambda- cyhalothrin	Matador 120 EC	187 mL	76 mL	1	Apply on a 4–7 day spray interval, depending on local pest pressure. Maximum 3 applications/yr. 24-hr re-entry interval.
		Silencer 120 EC	83 mL	34 mL	1	
	deltamethrin	Decis 5 EC	250–300 mL	101–121 mL	5	Maximum 2 ground or 1 aerial applications/yr.
	cypermethrin	Ripcord 400 EC	175 mL	71 mL	5	Maximum 3 ground or 2 aerial applications/yr.
		UP-Cyde 205 EC	280 mL	113 mL	5	European corn borer only. 12-hr re-entry interval.
	permethrin	Pounce 384 EC	275–375 mL	111–152 mL	1	Aerial or ground applications permitted. Maximum 2 aerial applications/yr. 12-hr re-entry interval.
		Perm-UP				
	Ambush 500 EC	200–275 mL	81–111 mL	1		
biological (group 11)	<i>Bacillus thuringiensis</i>	Dipel 2X DF	0.56–1.12 kg	0.22–0.45 kg		European corn borer only. Apply when pinhole feeding is observed on 5% of plants. Use high rate on large plants. Apply on a 7-day spray interval. Maximum 6 applications/yr.
		Bioprotec CAF	2.8–4.0 L	1.1–1.6 L		
carbamate (group 1A)	carbaryl	Sevin XLR	2.5–4.0 L	1–1.6 L	1	
	methomyl	Lannate TNG	430–625 g	174–253 g	3	Use high rate for corn borer. 24-hr re-entry interval.
organophosphate (group 1B)	acephate	Orthene 75 SP	568–825 g	230–334 g	21	European corn borer only. Maximum 4 applications/yr. 5-day re-entry interval (workers must wear gloves in the field for 4 weeks after application).
spinosyn (group 5)	spinosad	Success 480 SC	83 mL	34 mL	7	European corn borer only. Use only on very small larvae and low populations. Maximum 2 applications/yr. Maintain a spray pH of 6 or greater.
		Entrust 80 W	50 g	20 g	7	
FALL ARMYWORM						
pyrethroid ² (group 3)	lambda- cyhalothrin	Matador 120 EC				Maximum 3 ground or 2 aerial applications/yr. 24-hr re-entry interval.
		Silencer 120 EC	83 mL	34 mL	1	
	permethrin	Pounce 384 EC	180 mL	73 mL	1	Aerial or ground applications permitted. Maximum 2 aerial applications/yr. 12-hr re-entry interval.
		Perm-UP				
		Ambush 500 EC				

¹ PHI = Pre-Harvest Interval (days).² Pyrethroid sprays rapidly degrade at temperatures over 26.5°C, and more frequent spray applications are often required. Spraying during cooler evening temperatures may increase the performance of these products.

Bee Warning

Bees often visit sweet and field corn to collect water and pollen. Spraying may cause bee poisoning. Many of the insecticides used to control sweet corn pests are highly toxic to bees.

Damage to bees is reduced when sprays are applied in the late evening when bees are not foraging. Do not treat when the wind is blowing. Avoid spray drift to roadsides and adjacent fields where plants might be in bloom.

Advise local beekeepers of spraying activity (see *Prevent Bee Poisoning*, on page 53).

FALL ARMYWORM

Fall armyworm are migratory pests. They usually arrive in Ontario slightly later than the corn earworm. The pale-green or tan-coloured larvae create large, rough holes in the leaves and the cob. The spray threshold is 5% feeding injury. Sprays used for corn borer and

corn earworm usually control the armyworm as well. See Table 9-99, *Sweet Corn - European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations*, this page.

CORN FLEA BEETLE

Identification: These small (2-mm), black beetles create elongated scratches on the leaves and transmit the Stewart's wilt virus. Beetle feeding is not a direct cause of yield loss.

Period of Activity: Beetles overwinter in the top 5 cm of the soil/residue. They emerge when soil temperatures reach 18°C. The first peak of activity is usually in late June. Mild winters favour beetle survival and increase the risk of Stewart's wilt transmission.

Thresholds: Susceptible varieties may require foliar control if more than 10% of the plants have severe feeding injury or there are more than 2 beetles per plant.

Management Notes: Insecticide seed treatments and varietal tolerance provide the best flea beetle control. Susceptibility to Stewart's wilt varies greatly between varieties. Many early hybrids are particularly vulnerable. See Table 9–96, *Sweet Corn Seed Treatments*, on page 194.

Foliar insecticides applied for cutworm control may also reduce adult flea beetle populations.

GRUBS

White grubs and European chafer are an occasional pest of sweet corn, especially on coarse, sandy-loam soils. They feed on the roots of emerging seedlings, causing them to wilt and die. White grubs have a 3-year life cycle and are most commonly associated with turf and berry crops. The European chafer is an annual grub. Its peak feeding activity occurs in May through mid-June. See Table 9–96, *Sweet Corn Seed Treatments*, on page 194.

For more information on integrated pest management in sweet corn, see the following OMAFRA Factsheets and publication:

- *European Corn Borer in Sweet Corn and Other Horticultural Crops*, Order No. 97-019
- *Corn Earworm*, Order No. 95-065
- *Managing Cutworms in Vegetable Crops*, Order No. 00-055
- Publication 12, *Sweet Corn Production Manual*

Birds

RED-WINGED BLACKBIRDS AND CROWS

Noisemakers, such as propane cannons and digital distress calls, are often used to scare birds away from sweet corn crops. For full effectiveness, start using these devices before the corn becomes attractive for feeding and move them around frequently. Avoid planting near marshy and wooded areas. Cultivars with ears well-covered by husks are somewhat resistant to bird damage. For complete bird control information, see *Birds*, on page 64.

Harvest and Storage

Sweet corn is harvested while the kernels are at the early milk stage. Quality declines quickly if cobs are left in the field past this stage. Under good storage conditions, supersweet varieties may last for up to 1 week. Normal (su) and sugar-enhanced (se) varieties lose quality after 2–3 days.

Remove the field heat from the crop as quickly as possible after harvest. Store at temperatures close to 0°C with a relative humidity of 95%–98%.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

SWEET POTATOES

Production Requirements

The sweet potato is a warm-season vegetable that requires sandy to sandy-loam soils low in organic matter. Sweet potatoes are ideally suited to 3,000 or more crop heat units and take 100–130 days to mature, depending on variety. Transplants (slips) should be planted in late May or early June, after the danger of frost is past. Avoid planting sweet potato following sod or in fields with a history of perennial weed or grass pressure.

Average Yield

Crop	per acre	per hectare
sweet potatoes	8,000–12,000 lb tablestock product	9,000–13,500 kg tablestock product

Cultivars

Slips (vine-cut transplant material) can be produced successfully in Ontario by bedding selected roots in a greenhouse, however, most growers import slips from certified U.S. propagators. Importation of plant material from outside Canada is regulated by the Canadian Food Inspection Agency (CFIA). Not all U.S. varieties can be successfully grown under Ontario conditions. In Ontario, Beauregard and Covington are the most commonly grown varieties.

Planting and Spacing

A finger-type vegetable transplanter is suitable for setting out slips.

Row spacing:	102–112 cm	40–44 in.
In-row spacing:	30–40 cm	12–16 in.
Target population:	24,700 plants/ha	10,000 plants/acre

Sweet potatoes are mechanically cultivated several times to warm the soil, control weeds and enhance hill formation to ease digging. Hills approximately 15 cm high and 40 cm wide should be in place prior to root initiation and vine growth.

Sweet potatoes are generally drought tolerant to Ontario climatic conditions. However, reductions in yield and quality may result if the crop receives too little, too much or irregular watering. During extremely dry periods from June to August, it may be necessary to apply two to three irrigations of 3.5 cm each.

Fertility

Fertility requirements have not yet been established for sweet potatoes in Ontario. However, a balanced fertility program based on a soil test can form the basis for good crop health. See Chapter 1, *Vegetable Crop Fertility*, for more information.

Some general guidelines can serve as a basis when initiating a sweet potato fertility program. A soil pH of 5.8–6.2 is ideal for optimum root development and maximum utilization of fertilizer nutrients. Relatively little nitrogen fertilizer is required by sweet potatoes, especially if they are planted in rotation with major cash crops, such as soybean.

With soil test values of 60 ppm P_2O_5 or greater, there is not likely to be a response to additional phosphorous. If a soil test shows a lesser amount of phosphorous, consider applying additional amounts at transplanting.

Potassium is removed by the crop in relatively large amounts as the roots contain about 1.5% K on a dry weight basis, however the exact potassium requirements of sweet potatoes have not been established for Ontario.

Note that fertilizer requirements, particularly nitrogen, will vary with cultivar. Covington sweet potatoes generally have a higher demand for nitrogen than does the Beauregard variety.

Integrated Pest Management

Diseases

STEM ROT AND SCURF

Scurf is a fungal disease that can be transmitted on transplants. For more information on damping-off and root rots, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

Ensure slips are disease-free and follow a 3–4-year rotation between sweet potato crops. See Table 9–100, *Sweet Potato Disease and Insect Control Recommendations*, next page.

SCLEROTINIA ROT

Sclerotinia, or white mould, is a fungal disease that attacks a wide variety of crops. Initial symptoms are a white, fluffy growth on vines, followed by the appearance of water-soaked lesions and small, black sclerotia. This disease is not often seen in Ontario sweet potatoes, but can be a problem in other sweet potato growing regions with similar climatic conditions.

Table 9–100. Sweet Potato Disease and Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
STEM ROT AND SCURF						
carbamate (group M3)	thiram	Thiram 75 WP	1.75 kg per 1,000 L water			Dip roots of sprouts for 30 seconds in suspension, then plant promptly.
SCLEROTINIA ROT						
biological	<i>Bacillus subtilis</i>	Serenade ASO	8–15 L	3.2–6 L	0	Disease suppression only. Begin applications when conditions are conducive to disease development. Repeat as needed on a 7–10-day interval.
POST-HARVEST DISEASES (BACTERIAL SOFT ROT)						
inorganic (group M1)	hydrogen peroxide	StorOx	100 mL/10 L water			Spray diluted solution on newly harvested tubers. Additional applications can be made daily as a direct injection into humidification water. Do not enter treated storage bins until hydrogen peroxide air concentrations are below safe levels.
EUROPEAN CHAFER GRUBS						
neonicotinoid (group 4)	imidacloprid	Admire 240 F Grapple Alias 240 SC	1.2 L	0.5 L	125	Apply in 200 L water per ha as a soil drench after transplanting and before foliage covers more than 25% of planting bed. Make only 1 application/yr. 24-hr re-entry interval.
FLEA BEETLES						
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83 mL	34 mL	7	Apply in a minimum of 100 L water/ha. Maximum 3 applications/yr. Allow 7 days between applications. Will also control leafhoppers. 24-hr re-entry interval.
TWO-SPOTTED SPIDER MITES						
tetronic and tetramic acid derivatives (group 23)	spiromesifen	Oberon Flowable	500–600 mL	202–243	7	Will also control whiteflies. Apply before mite populations begin to build up. Control may not be apparent for 2–3 wks, especially under cool temperatures. 12-hr re-entry interval.
APHIDS						
tetronic and tetramic acid derivatives (group 23)	spirotetramat	Movento 240 SC	220–365 mL	89–148 mL	7	Will also control psyllids and whiteflies. Most effective on young stages. Has slow activity; control may not be apparent for 2–3 weeks. 12-hr re-entry interval.

¹ PHI = Pre-Harvest Interval (days).

Some U.S. cultivars (e.g., Beauregard) may be resistant to this disease. See Table 9–100, *Sweet Potato Disease and Insect Control Recommendations*, this page.

SWEET POTATO FEATHERY MOTTLE VIRUS

Virus symptoms include chlorotic spots, often with purple borders, and mild stunting of plants. Symptoms vary with virus strain and sweet potato variety. Obvious symptoms are not always present. Most strains are not thought to have a significant impact on yield; however, some strains can cause symptoms on storage roots. The disease is transmitted in a non-persistent manner by aphids and can be transferred on infected slips. The main method of control is avoiding diseased plants through use of clean, virus-free planting material. For more information, see *Aphids*, on page 60, and *Viruses (General)*, on page 59.

Post-Harvest Diseases

Sweet potatoes are susceptible to a number of fungal and bacterial pathogens that enter tubers through wounds inflicted during harvesting and handling, causing rots in storage or during transport. Reduce the number of potential infection sites by minimizing injuries to roots during harvest and handling. If possible, harvest under dry soil conditions. Cure as soon as possible after harvest to heal wounds.

See Table 9–100, *Sweet Potato Disease and Insect Control Recommendations*, this page.

Insects

WIREWORMS, WHITE GRUBS, MILLPEDES, APHIDS

For identification and management information on these common vegetable insects affecting sweet potatoes, see Chapter 8, *General Pests of Vegetable Crops*.

on page 59, and Table 9-100, *Sweet Potato Disease and Insect Control Recommendations*, opposite page.

FLEA BEETLES

Adults are small, dark beetles that feed on foliage. The "shot-hole" feeding damage is not thought to significantly affect yields. In most areas where sweet potatoes are grown, larvae will also attack roots, leaving shallow, winding trails on the surface. Damage commonly occurs on the fibrous non-marketable roots.

MITES

Two-spotted spider mites are microscopic (≤ 1 mm), yellowish in colour and have two dark spots on the sides of their abdomen. They have sucking mouthparts that they use to pierce plant parts and suck out fluids. Mites are a sporadic pest of sweet potato in Ontario and usually have negligible impacts on root yield. For more information, see Table 9-100, *Sweet Potato Disease and Insect Control Recommendations*, opposite page.

Nematode Control

See *Nematodes*, on page 63.

Harvesting, Curing and Storage

In Ontario, the sweet potato harvest generally starts in early September and continues through October. Mow and side-cut the surface vine growth 1-7 days before the scheduled harvest. Take care not to wound the tender skin of the sweet potato. It is not uncommon

to cull 30%-40% of the undersized, wounded or misshapen roots in the field.

Move the sweet potatoes into the curing facility immediately after digging. During curing, maintain temperatures of 26°C-29°C and relative humidity of 85%-95% for 3-7 days. Adequate ventilation and air circulation in the curing facility is critical. Curing should stop once sprouts begin to form.

Once cured, sweet potatoes can be stored for several months at 13°C-16°C and 85%-90% relative humidity.

Chilling injury (exposure of roots to temperatures below 10°C) can greatly increase root susceptibility to decay in storage. Harvest before soil temperatures drop below 10°C for prolonged periods. Do not leave harvested roots in the field overnight. Chilling injury can also occur in storage if temperatures drop below 10°C.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

TOMATOES

Production Requirements

Tomatoes perform well on a wide range of mineral soil types, but good drainage is essential. Lighter soils produce earlier crops and facilitate mechanical harvesting. A soil pH range of 6.0–6.8 is optimal.

In Ontario, tomatoes are established using greenhouse-produced transplants. Fresh-market varieties grown in Ontario require 58–80 days from transplanting to harvest. Processing varieties require from less than 100 to over 130 days. Harvest begins 6–10 weeks after pollination.

Recommended rotational crops: beans, brassica crops, cereal crops, corn, peas, soybeans

Do not rotate with: eggplant, peppers, potatoes

Average Yields

Crop	per acre	per hectare
Fresh market	8–14 tons	18–31 tonnes
Cherry tomatoes	2.5–3.5 tons	5.5–8 tonnes
Processing	32–40 tons	72–90 tonnes

Cultivars

Fresh-market tomato growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 236. Growers of tomatoes for processing must grow varieties specified by the processor.

See *Transplanting*, on page 39, for information on producing tomato transplants.

Plasticulture

Fresh-market tomatoes respond well to plastic mulch, row covers and drip irrigation. However, keep in mind that tomatoes are sensitive to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature inside the row cover regularly and ventilate when it reaches 35°C or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose a mulch that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. High tunnels are another option to extend the field tomato production season. For more information, see *Season Extension*, on page 34.

Table 9–101. Tomato Plant Spacing

Type	Row Spacing	In-Row Spacing	Bed Centres
Fresh Market			
Large vined (indeterminate)	1.5–1.8 m (5–6 ft)	50–70 cm (20–27 in.)	
Small vined (determinate and semi-determinate)	0.9–1.5 m (3–5 ft)	30–60 cm (12–24 in.)	
Processing (Machine Harvest)			
Twin row system	45 cm (18 in.)	38–45 cm ¹ (15–18 in.)	1.5–1.65 m (5–5.5 ft)
Single row system	75 cm (30 in.)	38–45 cm ¹ (15–18 in.)	

¹ For small-vined, early-season processing varieties, in-row spacing can be reduced to 33–38 cm (13–15 in.).

Plant Spacing

Table 9–101, *Tomato Plant Spacing*, this page, shows spacing for both fresh-market and processing types of tomatoes. Machine harvest varieties may be grown in twin or single rows, with or without raised beds, depending on the harvest equipment. The improved air circulation associated with single rows may help reduce foliage and fruit disease.

Fertility

Nitrogen

Fresh-Market Tomatoes

For non-fertigated fresh market tomatoes, apply nitrogen according to Table 9–102, *Non-Fertigated Tomato Nitrogen Recommendations*, this page. Avoid late side-dress applications. They may prune the roots and trigger blossom-end rot.

Table 9–102. Non-Fertigated Tomato Nitrogen Recommendations

	Actual N kg/ha
Fresh-Market	
Preplant	35–50
Side-dress (applied after the first fruit are set)	35–50
Total	70–100
Processing – Hybrid	
Coarse sand and sandy loams: <2% organic matter	160–180
Loams, silt loams and sandy loams: >2% organic matter	90–120
Processing – Open-Pollinated	
Coarse sand and sandy loams: <2% organic matter	100–120
Loams, silt loams and sandy loams: >2% organic matter	70–90

Table 9-103. Fertigated Tomato Nitrogen Recommendations

Timing	Actual N kg/ha
Fresh Market Tomatoes – on all soils	
Processing Tomatoes – on all soils (except coarse-textured soils containing less than 3.2% organic matter)	
Preplant (broadcast)	35–50
Transplanting to fruit set	2.5/week
Fruit sizing to harvest	5/week
Harvest	2.5/week
Processing Tomatoes – on coarse-textured soils containing less than 3.2% organic matter only	
Preplant (broadcast)	85–120
Week 1–3 (transplant to first bloom)	no fertigation
Week 4 (beginning of fruit set)	20–25/week
Week 5–7 (beginning of fruit sizing)	25–35/week
Week 8–9	20–25/week
Week 10	continue irrigation, no fertigation
Week 11 to harvest	no irrigation/ fertigation
Do not exceed 300 kg/ha total nitrogen applied during the season.	

For fertigated fresh market tomatoes, apply nitrogen according to the schedule in Table 9-103, *Fertigated Tomato Nitrogen Recommendations*, this page.

Processing Tomatoes

The nitrogen rate will vary greatly, according to variety, soil type, crop rotation, organic matter and soil management.

For tomatoes that are not fertigated, apply nitrogen as a preplant broadcast application according to the recommendations in Table 9-102, *Non-Fertigated Tomato Nitrogen Recommendations*, opposite page.

For fertigated tomatoes, broadcast and incorporate the recommended preplant nitrogen. Apply the remainder of the nitrogen according to Table 9-103, *Fertigated Tomato Nitrogen Recommendations*, this page.

The nitrogen rate for fertigated processing tomatoes on coarse-textured soils with organic matter levels of 2.5%–3.2% is very specific to these soils. The supporting research was conducted near Harrow, on Granby sandy loam and Granby loamy sand soils. There is no research showing a benefit of this higher fertigation rate on other soil types. All other soils should use the alternative fertigation recommendation.

Cover crops planted immediately following the harvest of vegetable crops help manage residual soil nitrogen and nitrogen release from plant residue.

Table 9-104. Fertigated Tomato Potassium Recommendations

Timing	Actual K ₂ O kg/ha
Preplant	35–50
Transplanting to fruit set	2.5/week
Fruit sizing to harvest	5/week
Harvest (fresh market)	2.5/week
Alternatively, potassium can be applied 100% preplant, according to Table 1-12 on page 15.	

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, tomatoes are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1-10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Broadcast all phosphorus preplant. When fertigating, never apply phosphorus through the drip line.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, fresh-market and paste tomatoes are unlikely to respond to additional potash applications. For whole-pack tomatoes, use a higher threshold of 250 mg K per L soil (ppm).

For soils testing lower than the threshold values listed above, see Table 1-12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15. For fertigated tomatoes, apply potash 100% preplant, or split between preplant and fertigation, according to the recommendations in Table 9-104, *Fertigated Tomato Potassium Recommendations*, this page.

Starter Solution (All Tomatoes)

Apply a high-phosphorus starter fertilizer in the transplant water when transplanting tomatoes. Starter fertilizer is especially important when planting in cool soils. Starter fertilizers are available in several forms, including liquids (e.g., 10-34-0 or 6-24-6), soluble or granular materials (e.g., 10-30-20 or 10-52-10). Apply according to the recommendations in Table 9-105, *Tomato Starter Solution Recommendations*, this page.

Table 9-105. Tomato Starter Solution Recommendations

Soil Temperature	Starter Concentration ¹
below 18°C	Use full label rate as recommended.
18°C–27°C	Use half of recommended rate.
above 27°C	Starter not normally required.

¹ Under dry conditions or in sandy soils with less than 2% organic matter, use half the recommended rates.

Table 9–106. Tomato Transplant Production Disease and Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	Notes
DAMPING-OFF, ROOT ROT					
phenylamide (group 4)	metalaxyl-M and S-isomer	Apron XL-L5	20–40 mL/100 kg of seed		Seed treatment. Pythium damping-off . One application per year. For import use only – not for domestic commercial or on-farm treatment.
carbamate (group M3)	thiram	Thiram 75 WP	65–80 g/25 kg of seed		Seed treatment. Seed decay, seedling blight, damping-off .
phthalimide (group M4)	captan	Maestro 80 DF	1.25 kg/1,000 L of water		Soil drench treatment. Damping-off, fungus root rot . 48-hr re-entry interval.
		Supra Captan 80 WDG	Apply 50–85 L of solution per 100 m ² (1,076 ft ²).		
dithiocarbamate (group M2)	oxine benzoate	No-Damp	10 mL/L of water		Soil treatment. Damping-off .
BOTRYTIS GREY MOULD					
hydroxanilide (group I7)	fenhexamid	Decree 50 WDG	1.5 kg	607 g	Maximum 2 applications per crop cycle. 60-day pre-harvest interval. 4-hr re-entry interval.
BACTERIAL DISEASE					
inorganic (group M1)	copper hydroxide	Kocide 2000	3.2 kg	1.3 kg	Apply every 5 days, when warranted, to a maximum of 5 applications over a 4-week period prior to transplanting. Apply in low water volumes. 24-hr re-entry interval.
INSECTS – DUPONCHELIA FOVEALIS					
biological (group I1)	<i>Bacillus thuringiensis</i>	Bioprotec 3P	800 g/1,000 L of water		Apply the product such that it flows along the stem, coating it well, and into the top layer of the soil around the base of the plant. Thorough coverage of foliage and stems is necessary.

Magnesium

A magnesium deficiency may occur on tomatoes. The usual symptoms are yellowing of older leaves while the veins remain dark green. Excessive potash applications may induce a magnesium deficiency. Reduce potassium fertilizer rates on soils testing less than 100 ppm magnesium. Adjust the potassium rate proportionally to a minimum of 50% at 50 ppm Mg. See *Micronutrients*, on page 17, and Table 1–13, *Magnesium, Calcium and Micronutrient Fertilizer Sources*, on page 16.

Plant Analysis

When used in conjunction with soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see *Plant Tissue Analysis*, on page 3.

Integrated Pest Management

For more information on integrated pest management in tomatoes, see the OMAFRA publication, *Ontario CropIPM*, Order No. AF121.

Transplant Production — Disease and Insect Management

Bacterial spot is a serious disease of tomatoes. Talk to your seed supplier to ensure that proper seed disinfectant treatments have been used. A greenhouse spray program with a fixed copper fungicide can greatly reduce the field infection rate later in the season. Apply every 5 days, starting 2½ weeks after seeding. Use low water volumes — wet the foliage, but not to excessive runoff. Ensure foliage is dry when shipping plants.

See Table 9–106, *Tomato Transplant Production Disease and Insect Control Recommendations*, this page, and *Bacterial Disease Control With Copper Fungicides*, on page 208.

For more information on vegetable transplant production, see Chapter 5, *Seeding and Transplanting*, on page 37.

Duponchelia fovealis is a moth that has recently been found in some Ontario greenhouses. It has a broad host range that includes vegetables. The larvae feeds on host plants. The presence of the pest can lead to trade restrictions for crops being exported to the U.S. Any suspected findings of *Duponchelia fovealis* must be reported to the CFIA. The pest does not survive winters outside of the greenhouse.

Table 9-107. Activity of Fungicides on Tomato Diseases

Common Name	Trade Name	Greenhouse (transplants)			Field						
		Damping-Off (Seedlings)	Grey Mould (Botrytis)	Bacterial Spot	Anthracnose	Bacterial Disease ¹	Early Blight	Grey Mould (Botrytis)	Late Blight	Powdery Mildew	Septoria Leaf Spot
oxine benzoate	No-Damp	✓									
fenhexamid	Decree 50 WDG		✓								
chlorothalonil	Bravo 500				✓		✓	✓	✓		✓
mancozeb	Dithane DG				✓		✓		✓		
	Manzate Pro-Stick				✓		✓		✓		
	Penncozeb 80 WP				✓		✓		✓		
metiram	Polyram DF				✓		✓		✓		
azoxystrobin	Quadris Flowable				✓		✓		✓		✓
pyraclostrobin	Cabrio EG				✓		✓		✓		✓
boscalid	Lance WDG						✓	✓			
famoxadone/ cymoxanil	Tanos 50 DF						✓		✓		
mandipropamid	Revus								✓		
copper hydroxide	Parasol Flowable					✓	✓		✓		✓
	Kocide 2000			✓			✓				✓
<i>Bacillus subtilis</i>	Serenade ASO					+	+	+		+	
captan	Maestro 80 DF	✓			✓						✓
	Supra Captan 80 WDG	✓			✓						✓

✓ = control

+ = suppression

¹ See label for details.

Diseases

See Table 9-107, *Activity of Fungicides on Tomato Diseases*, this page. Ratings in the shaded boxes indicate that the disease is listed on the product label. Always consult the product label for registered uses and additional use specifications. Use fungicides only for the crop and disease combinations listed on the product label. Additional information is provided in this table to help the grower choose the best fungicide for control of diseases listed on the product label.

DAMPING-OFF AND ROOT ROT

For identification and management information on these common vegetable diseases, see Chapter 8, *General Pests of Vegetable Crops*, on page 59.

To prevent damping-off, use sterile, soil-less mix for growing seedlings. Fungicides registered for greenhouse transplant production are listed in Table 9-106, *Tomato Transplant Production Disease and Insect Control Recommendations*, opposite page. Also see Chapter 5, *Seeding and Transplanting*, on page 37.

ANTHRACNOSE

Identification: Fruit symptoms appear as small, sunken, water-soaked, circular spots. Lesions gradually expand,

reaching up to 20 mm (¾ in.) in diameter, developing a pattern of concentric rings. The lesions darken, and small black fungal structures appear in the centre. Anthracnose lesions on leaves are inconspicuous.

Development: Infections can take place under a wide range of temperatures from 10°C–30°C. Rapid development occurs during periods of prolonged leaf wetness. While symptoms appear only on ripe fruit, infection can be initiated on green fruit. It is critical that green fruit be adequately protected with a fungicide program.

Thresholds: See *TOMcast*, on page 207. There is little tolerance for anthracnose in processing crops, where fruit must be held in the field and the taste of the product can be affected. Do not delay initial fungicide applications beyond July 11 (July 18 for very late plantings).

Management Notes: Follow a minimum 3-year rotation with non-solanaceous crops. Control weeds that can act as hosts. Use disease-free or treated seed. Properly timed fungicide sprays are effective at reducing losses to this disease. See Table 9-108, *Tomato Fungal Disease Control Recommendations*, next page.

Table 9–108. Tomato Fungal Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
ANTHRACNOSE, EARLY BLIGHT, LATE BLIGHT, SEPTORIA LEAF SPOT						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.4–4.0 L	1–1.6 L	1	48-hr re-entry interval.
dithiocarbamate (group M3)	mancozeb	Dithane DG	1.75–3.25 kg	0.71–1.31 kg	7	Early blight, anthracnose, late blight only. 24-hr re-entry interval.
		Manzate Pro-Stick				
	metiram	Penncozeb 80 WP	1.1–3.25 kg	0.4–1.31 kg	7	Low rate for early and late blight; high rate for anthracnose and septoria leaf spot.
QoI (group 11)	azoxystrobin	Quadris Flowable	300–500 mL	121–202 mL	1	Early blight, anthracnose only. Maximum 3 applications/yr. Do not apply for 21 days after transplanting. Do not apply for 6 days before or after using metribuzin.
	pyraclostrobin	Cabrio EG	560–840 g	227–340 g	0	Use up to 1 kg/ha (400 g/acre) for late blight. Maximum 6 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group (one for late blight). 12-hr re-entry interval.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	71–127 g	0	Early blight only. Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry interval.
QoI + acetamide (group 11 + group 27)	famoxadone + cymoxanil	Tanos 50 DF	560–840 g	227–340 g	3	Early blight and late blight only. Do not apply sequential applications of any QoI fungicide or of any tank-mix containing a QoI fungicide. 24-hr re-entry interval.
inorganic + dithiocarbamate (group M1 + group M3)	copper hydroxide + mancozeb	Parasol Flowable + Dithane DG	2.3 L + 1.87–2.4 kg	0.9 L + 0.76–1 kg	7	Septoria leaf spot, early blight and late blight only. Apply at 7–10-day intervals or more frequently when disease is severe.
		Parasol Flowable + Manzate Pro-Stick	2.3 L + 1.87–2.4 kg	0.9 L + 0.76–1 kg	7	
inorganic (group M1)	copper hydroxide	Kocide 2000	2.24–2.52 kg	0.9–1.02 kg	1	Early blight and septoria leaf spot only.
phthalimide (group M4)	captan	Maestro 80 DF	2.75–4.25 kg	1.11–1.72 kg	2	Anthracnose and septoria leaf spot only. Use high rate on mature plants or for severe infections. 48-hr re-entry interval.
		Supra Captan 80 WDG				
carboxylic acid amides (group 40)	mandipropamid	Revus	400–600 mL	162–243 mL	1	Late blight only. The use of a non-ionic adjuvant (0.125% v/v) is recommended. Maximum 4 applications/season. A tank mix with Bravo 500 is recommended. 12-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	8–15 kg	3–6 kg	0	Early blight suppression only. Also suppresses powdery mildew. Make first application when conditions are conducive for disease development.
BOTRYTIS GREY MOULD						
carboxamide (group 7)	boscalid	Lance WDG	420 g	170 g	0	Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry interval.
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	4–15 kg	1.6–6 kg	0	Suppression only. Make first application when conditions are conducive for disease development.

¹ PHI = Pre-Harvest Interval (days).

TOMcast

The TOMcast program is available in some growing areas to help field tomato growers determine the optimum time to apply foliar fungicides for the control of early blight, septoria leaf spot and anthracnose.

A network of weather stations monitors conditions affecting disease development. The weather data is used to calculate disease severity values (DSVs) throughout the growing season. Growers are advised to spray when a critical number of DSVs have accumulated since planting or since the last fungicide application. For more information, contact Weather Innovations Incorporated at 519-352-5334 or see their website at www.weatherinnovations.com.

If the TOMcast service is unavailable, begin a preventative spray program when the first fruits are about walnut size. Repeat sprays as necessary. Repeat at 5–7-day intervals during continuous moist weather. Extend the schedule to 12–14 days in warm, dry weather if diseases are under control. Applications should continue until close to harvest as anthracnose lesions can appear on unprotected fruit within 5–6 days in favourable conditions.

EARLY BLIGHT

Identification: Circular spots with dark, concentric rings (target spots) develop on the older foliage. Severe infections spread to younger leaves. Fruit infections are not common, but may appear as blackened areas at the stem-end.

Development: Early blight overwinters in infected crop residue. Spores are present throughout the growing season and may be carried long distances in the wind. Temperatures of 17°C–24°C and extended leaf wetness favour early blight development.

Thresholds: See TOMcast.

Management Notes: Reduce early blight inoculum by following a 3- to 4-year crop rotation. Ensure transplants are healthy and free of disease. Cultivars vary in tolerance to early blight. See Table 9–108, *Tomato Fungal Disease Control Recommendations*, opposite page.

SEPTORIA LEAF SPOT

Identification: Lower leaves develop numerous small, dark, circular spots up to 5–6 mm in diameter. Spots have a dark margin with a lighter centre. Tiny, black fungal structures (pycnidia) develop in the centre of the lesions. Rapid defoliation may occur if left untreated.

Development: Plants are most susceptible after fruit set. Septoria leaf spot prefers warm temperatures of 20°C–25°C and extended periods of leaf wetness caused by overhead irrigation, rain or heavy dews.

Thresholds: See TOMcast.

Management Notes: Ensure disease-free seed and transplants. Rotate crops and control solanaceous weeds, such as nightshade. See Table 9–108, *Tomato Fungal Disease Control Recommendations*, opposite page.

BACTERIAL SPOT AND BACTERIAL SPECK

Identification: It can be difficult to distinguish between these two diseases. Small, dark lesions develop on the leaves. The infected tissue of either disease may exhibit a yellow halo. Lesions also occur on stems and flower buds. Severe infections may cause defoliation and loss of flowers.

These diseases initiate lesions on green fruit. Bacterial spot–infected fruit develop small, raised, dark spots. Young lesions may have a white halo, similar to bacterial canker. Spots increase in size to 4–6 mm in diameter and develop brown, corky centres.

Bacterial speck fruit lesions are small (less than 2 mm in diameter), black, slightly raised and often surrounded by a narrow, green-to-yellow halo. Speck lesions on the fruit are usually superficial and can be scraped off.

Development: Bacterial spot prefers warm temperatures of 24°C–30°C. Bacterial speck favours cooler weather: 18°C–24°C. Abundant rainfall and high humidity aid infection of both diseases.

Thresholds: None have been established. Tolerance for either disease is low in fresh-market or processing tomatoes (wholepack and diced) due to marketability and peeling issues.

Management Notes: All tomato seed should be disinfected by the supplier, using acid or chlorine treatment. Do not plant diseased transplants. Copper fungicides may be effective in slowing bacterial spot development, but only if applied early and often. Bacterial speck populations in Ontario show resistance to copper. See Table 9–109, *Tomato Bacterial Disease Control Recommendations*, next page.

Note: Avoid working in fields when foliage is wet. Wash machinery with a high-pressure washer after working in contaminated fields. If possible, schedule overhead irrigation early in the day to allow the foliage time to dry before nightfall or consider a drip irrigation system.

BACTERIAL CANKER

Identification: Early (systemic) infections from infected seed or seedlings are of greatest concern. They cause the plant to wilt, often on only one side. Streaking or

Table 9–109. Tomato Bacterial Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
inorganic + dithiocarbamate (group M1 + group M2)	copper hydroxide + mancozeb	Kocide 2000 + Dithane DG	3.2 kg + 1.87–2.4 kg	1.3 kg + 0.76–1 kg	7	Apply 7 days after transplanting and repeat at 7-day intervals for at least 3 applications. Apply more frequently under wet conditions. If wet conditions persist, continue applications until early bloom. 24-hr re-entry interval.
		Parasol Flowable + Dithane DG	2.3 L + 1.87–2.4 kg	0.9 L + 0.76–0.1 kg	7	
		Parasol Flowable + Manzate Pro-Stick	2.3 L + 1.87–2.4 kg	0.9 L + 0.76–0.1 kg	7	
microbial (group 44)	<i>Bacillus subtilis</i>	Serenade ASO	4–15 kg	1.6–6 kg	0	Suppression only. Begin applications soon after transplant. Repeat as necessary on a 7–10-day interval. When conditions are conducive to rapid disease development, use in a rotational program with other bactericides.

¹ PHI = Pre-Harvest Interval (days).

open cankers may appear on the stems and a light, reddish-brown discolouration may be seen in the vascular tissue, just above the soil line.

The more common, and less severe, secondary infections show up later in the season. Leaves develop brown-to-black margins with a thin, yellow border. Leaflet edges usually curl upwards.

Infected fruit may develop “bird’s-eye” spots — small lesions with light brown centres and a greasy white halo.

Development: Warm, wet weather conditions with temperatures of 24°C–32°C favour the spread of this disease.

Management Notes: Use disease-free or disinfected seed and disease-free transplants. Copper fungicides may slow canker development. See *Bacterial Disease Control With Copper Fungicides* and Table 9–109, *Tomato Bacterial Disease Control Recommendations*, this page.

Bacterial Disease Control With Copper Fungicides

In the greenhouse, apply 4–5 applications of a registered fixed copper product, every 5 days, starting 16–18 days after seeding. Use low water volumes. Wet the foliage, but do not soak the plug media. Apply fungicides after the last watering of the day. Ensure foliage is dry when shipping plants.

In the field, apply a copper spray within 7 days of transplanting or within 5 days if the weather is wet (rain, fog, dew) or the greenhouse program was not followed.

Repeat copper applications at 7-day intervals for at least 3 applications. Continue applications until early fruit set if wet conditions prevail or if plants are under stress. Bacterial speck populations in Ontario show resistance to copper.

Research has shown that tank-mixing mancozeb with copper enhances bacterial disease control.

For more information on bacterial diseases, see the OMAFRA Factsheet, *Bacterial Diseases of Tomato: Bacterial Spot, Bacterial Speck, Bacterial Canker*, Order No. 05-069.

LATE BLIGHT

Identification: Late blight causes rapid and severe defoliation. Pale green-to-brown water-soaked spots develop on the leaves. Lesions enlarge rapidly and become brown to purplish-black. A grey-to-white mouldy growth may develop on the underside of infected leaves, especially under conditions of high humidity. Brownish cankers on leaf petioles and stems may girdle and kill the plant. Fruit lesions are firm and greasy in appearance, with greyish-green or brown blotches.

Development: Cool nights and warm days (15°C–21°C), with moist weather, are ideal for disease development.

Thresholds: No tolerance. This disease is easily spread by wind and can rapidly destroy the crop.

Management Notes: Preventative fungicide sprays for early blight, septoria and anthracnose also protect against late blight. If the disease is present in the area, follow a 5–7-day fungicide schedule, using fungicides recommended specifically for late blight control. For more information about management practices for reducing late blight, see *Late Blight*, on page 160. See also Table 9–108, *Tomato Fungal Disease Control Recommendations*, on page 206.

VERTICILLIUM WILT

Identification: Yellow, v-shaped lesions develop on the lower leaves. Symptoms often appear only on one side of the plant or one side of the leaf. Split the plant stem at the base to check for discolouration of vascular tissue. In severe cases, infected plants may wilt, especially during the heat of the day.

Table 9-110. Activity of Insecticides on Tomato Pests

Common Name	Trade Name	Aphids	Cabbage Looper	Colorado Potato Beetle	Cutworms	Drosophila (Fruit Fly)	Hornworm	Spider Mite	Stink Bug	Tarnished Plant Bug	Tomato Fruitworm	Wireworm
<i>Bacillus thuringiensis</i>	Bioprotec 3P		✓				✓				✓	
	Novodor			✓								
	Thuricide HPC		✓				✓					
	Dipel 2X DF		✓				✓				✓	
acetamiprid	Assail 70 WP	✓		✓								
thiamethoxam	Actara 240 SC	✓										
spirotetramat	Movento 240 SC	✓										
chlorantraniliprole	Coragen			✓								
endosulfan	Thiodan 4 EC	✓		(✓)			✓					
	Thionex 50 WP	✓		(✓)			✓				✓	
diazinon	Diazinon 50 W	(✓)				✓						
	Diazinon 500 E	(✓)				✓						
dimethoate	Cygon 480	✓										
	Lagon 480	✓										
malathion	Malathion 25 W	(✓)		(✓)				(✓)		✓		
	Malathion 500 E	(✓)						(✓)				
acephate	Orthene 75 SP	✓		(✓)	✓							✓
methomyl	Lannate TNG	✓			✓						✓	
imidacloprid	Admire 240 F			✓								
	Alias 240 EC			✓								
	Grapple			✓								
cyhalothrin-lambda	Matador 120 EC			✓	✓					✓		
	Silencer 120 EC			✓	✓					✓		
deltamethrin	Decis 5 EC			✓								
cypermethrin	Ripcord 400 EC			✓								
	UP-Cyde 2.5 EC			✓								
permethrin	Pounce 384 EC			✓	✓		✓				✓	
	Perm-UP			✓	✓		✓				✓	
	Ambush 500 EC			✓	✓		✓				✓	
spinosad	Success 480 SC		✓	✓								
	Entrust 80 W		✓	✓								
spinetoram	Delegate WG		✓									
carbaryl	Sevin XLR			(✓)	✓		✓		✓	✓	✓	
naled	Dibrom					✓	✓				✓	
spiromesifen	Oberon Flowable							✓				
dicofol	Kelthane 50 W							✓				

✓ = control

() = on label but not considered effective or resistance documented

Development: Verticillium wilt is present all season. However, symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes may increase the severity of verticillium wilt.

Thresholds: Soil *Verticillium*, root knot and root lesion nematode counts, available from the Pest Diagnostic Clinic, University of Guelph, will help determine the need for control measures. See Appendix G, *Diagnostic Services*, on page 240.

Management Notes: Follow a 4-6-year crop rotation. Do not rotate with related crops, strawberries or raspberries. Keep fields clean of host weeds such as nightshades. Cultivars tolerant to verticillium wilt are available. Soil fumigation may be required if *Verticillium* and nematode counts are high. See *Nematodes*, on page 63.

VIRUSES (CUCUMBER MOSAIC, TOMATO MOSAIC, STREAK, TOMATO SPOTTED WILT)

Identification: Symptoms vary between viruses, cultivars and conditions. Interaction between viruses may occur, complicating visual diagnosis.

Table 9-111. Tomato Cutworm and Aphid Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
CUTWORMS						
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC	83 mL	34 mL	7	Apply in the late evening or at night. Do not disturb the soil for 5 days after application. 24-hr re-entry interval.
		Silencer 120 EC				
	permethrin	Pounce 384 EC	180-260 mL	73-105 mL	0	Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application. Use high rate on large larvae, dry soils or muck soils. 12-hr re-entry interval.
		Perm-UP				
carbamate (group 1A)	carbaryl	Ambush 500 EC	140-200 mL	57-81 mL	1	
		Sevin XLR	45 mL/ 100 m of row	14 mL/ 100 ft of row	2	
	methomyl	Lannate TNG	270-540 g	109-219 g	1	
organophosphate (group 1B)	acephate	Orthene 75 SP	1.2 kg in 2,000 L water	0.5 kg in 180 gal water		Also controls wireworm. Based on 14,000 plants/ha. Transplanting water treatment only. Caution: Temporary plant damage may occur on light sandy soils or if the rate used is too high. 12-hr re-entry interval.
APHIDS						
neonicotinoid ² (group 4)	acetamiprid	Assail 70 WP	56-86 g	23-35 g	7	Maximum 2 applications/yr. Alternate applications with other insecticide groups. 12-hr re-entry interval.
	thiamethoxam	Actara 25 WG	105 g	42 g	1	Alternate applications with other insecticide groups. 12-hr re-entry interval.
tetronic and tetramic acid derivatives (group 23)	spirotetramat	Movento 240 SC	220-365 mL	89-148 mL	1	Most effective on young stages. Has slow activity; control may not be apparent for 2-3 weeks. 12-hr re-entry interval.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	1.5-2.75 L	0.6-1.11 L	2	
		Thionex 50 WP	1.1 kg	0.4 kg	2	
organophosphate (group 1B)	diazinon ³	Diazinon 50 W	1.1-1.75 kg	0.4-0.71 kg	1	Less effective below 20°C.
		Diazinon 500 E	1.1-1.7 L	0.4-0.7 L	1	
	dimethoate	Cygon 480	0.55-1.1 L	0.22-0.4 L	7	
		Lagon 480				
	malathion ³	Malathion 25 W	2.75-4.25 kg	1.11-1.72 kg	3	Less effective below 20°C.
		Malathion 500 E	1.5-2.0 L	0.6-0.8 L	3	
	acephate	Orthene 75 SP	1.2 kg in 2,000 L water	0.5 kg in 180 gal water		Based on 14,000 plants/ha. Transplanting water treatment only. Temporary plant damage may occur on light sandy soils or if the rate used is too high. 12-hr re-entry interval.
carbamate (group 1A)	methomyl	Lannate TNG	270-540 g	109-218 g	1	

¹ Pre-Harvest Interval (days).² Do not apply a foliar neonicotinoid in the same season as a soil application.³ Control of aphids with diazinon and malathion has been inconsistent in many areas.

Period of Activity: Cucumber mosaic is spread by aphids. Thrips are a vector for tomato spotted wilt. The presence of these diseases usually follows periods of high aphid or thrips activity. Tomato mosaic and the streak viruses are spread mechanically.

Management Notes: Control weed hosts in and around the field. Pigweeds, nightshades and related weeds, milkweed, purslane, chickweed and many other plants are alternate hosts of the cucumber mosaic virus. See *Aphids*, on page 60. Tomato spotted wilt virus is rarely of economic concern.

Insects

See Table 9-110, *Activity of Insecticides on Tomato Pests*, previous page. Ratings in the shaded boxes indicate

that the insect is listed on the product label. Always consult the product label for registered uses and additional use specifications. Use insecticides only for the crop and insect combinations listed on the product label. Additional information is provided in this table to assist the grower in choosing the best insecticide for control of insects listed on the product label.

CUTWORMS, WIREWORM, APHIDS

For identification and management information on these common vegetable insects affecting tomatoes, see Chapter 8, *General Pests of Vegetable Crops*, on page 59, and Table 9-111, *Tomato Cutworm and Aphid Control Recommendations*, this page.

Table 9-112. Tomato Colorado Potato Beetle Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
Transplant Treatment						
neonicotinoid ² (group 4)	imidacloprid	Admire 240 F	7–10 mL / 100 m of row	2–3 mL / 100 ft of row		Apply in-furrow at transplanting. Consult the label for application details. Alternate applications with other insecticide groups.
		Alias 240 EC				
		Grapple				
organophosphate (group 1B)	acephate	Orthene 75 SP	1.2 kg in 2,000 L of transplant water	0.5 kg in 180 gal of transplant water		Based on 14,000 plants/ha. Transplanting water treatment only. Caution: Temporary plant damage may occur on light sandy soils or if the rate used is too high. 12-hr re-entry interval.
Foliar Treatment						
diamide (group 28)	chlorantraniliprole	Coragen	250–375 mL	101–152 mL	1	Early application on larval stages provides best control. 12-hr re-entry interval.
biological (group 11)	<i>Bacillus thuringiensis</i>	Novodor	4.0–8.0 L	1.6–3.2 L	0	Field scouting is essential for timing of sprays.
neonicotinoid ² (group 4)	imidacloprid	Admire 240 F	200 mL	81 mL	7	Maximum 2 foliar applications/yr, at least 5 days apart. Alternate applications with other insecticide groups. 24-hr re-entry interval.
		Alias 240 EC				
		Grapple				
	acetamiprid	Assail 70 WP	40–80 g	16–32 g	7	Maximum 2 foliar applications/yr. Alternate applications with other insecticide groups. 12-hr re-entry interval.
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83–125 mL	34–51 mL	7	Use the higher rate for larger instars or higher populations of larvae. 24-hr re-entry interval.
		Silencer 120 EC				
	deltamethrin	Decis 5 EC	100–150 mL	40–61 mL	3	Maximum 3 applications/yr (1/yr on muck soils). Do not apply after August 1.
	cypermethrin	Ripcord 400 EC	85 mL	34 mL	3	12-hr re-entry interval.
		UP-Cyde	140 mL	57 mL	3	
	permethrin	Pounce 384 EC	180–260 mL	73–105 mL	0	12-hr re-entry interval.
		Perm-UP				
		A. nbush 500 EC	140–200 mL	57–81 mL	1	
spinosyn (group 5)	spinosad	Success 480 SC	83 mL	34 mL	1	Use only on small larvae and low infestations. Maximum 3 applications/yr. Maintain a spray water pH of 6 or greater.
		Entrust 80 W	50 g	20 g	1	

¹ Pre-Harvest Interval (days).² Do not apply a foliar neonicotinoid in the same season as a soil application.**COLORADO POTATO BEETLE**

Identification: Adults are orange with 10 black stripes on the wings. Larvae are red-to-orange with two rows of black spots along their sides.

Period of Activity: Feeding damage is mainly a concern early in the season when plants are small.

Thresholds: 0.5 adults or larvae per plant in the first 2 weeks after transplanting or 1 adult or larvae per plant later in the season.

Management Notes: Rotate crops and avoid planting tomatoes adjacent to beetle overwintering sites (previous year's tomato, eggplant or potato fields). Chemical controls are most effective when applied to

small larvae. For more information, see *Colorado Potato Beetle*, on page 168. See Table 9-112, *Tomato Colorado Potato Beetle Control Recommendations*, this page.

Warning

In a number of counties and regions, Colorado potato beetles have developed a strong resistance to certain insecticides. To slow development of further resistance, it is essential to rotate between chemical groups each time a spray is applied.

Table 9-113. Tomato Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI ¹	Notes
TARNISHED PLANT BUG						
pyrethroid (group 3)	lambda- cyhalothrin	Matador 120 EC Silencer 120 EC	83 mL	34 mL	7	24-hr re-entry interval.
organophosphate (group 1B)	dimethoate	Lagon 480	0.55-1.1 L	0.22-0.4 L	7	
carbamate (group 1A)	carbaryl	Sevin XLR	5.25-6.4 L	2.1-2.6 L	2	
HORNWORM						
biological (group 11)	<i>Bacillus thuringiensis</i>	Thuricide HPC Dipel 2X DF Biprotec 3P	0.75-1.5 L 140-275 g 320-560 mL	0.3-0.6 L 57-110 g 130-227 mL	0 0 0	Most effective against small larvae.
pyrethroid (group 3)	permethrin	Pounce 384 EC Perm-UP Ambush 500 EC	180-260 mL 140-200 mL	73-105 mL 57-81 mL	0 1	12-hr re-entry interval.
carbamate (group 1A)	carbaryl	Sevin XLR	2.5-5.25 L	1.0-2.12 L	2	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC Thionex 50 WP	1.5-2.75 L 1.1 kg	0.6-1.11 L 0.4 kg	2 2	
CABBAGE LOOPER						
biological (group 11)	<i>Bacillus thuringiensis</i>	Thuricide HPC Dipel 2X DF Biprotec 3P	2.0-4.25 L 275-550 g 0.72-1.45 L	0.8-1.72 L 111-223 g 0.29-0.59 L	0 0 0	Most effective against small larvae.
spinosyn (group 5)	spinetoram	Delegate WG	140-200 mL	57-81 mL	1	12-hr re-entry interval.
DROSOPHILA (FRUIT FLY)						
organophosphate (group 1B)	diazinon	Diazinon 50 W Diazinon 500 E	1.1-1.75 kg 1.1-1.7 L	0.4-0.7 kg 0.4-0.7 L	1 1	
	naled	Dibrom	1.1 L	0.4 L	4	48-hr re-entry interval.
TWO-SPOTTED SPIDER MITE						
tetrone and tetramic acid derivatives (group 23)	spiromesifen	Oberon Flowable	500-600 mL	202-243 mL	7	Maximum 3 applications/yr. Apply before mite populations begin to build up. Control may not be apparent for 2-3 wks, especially under cool temperatures. 12-hr re-entry interval.

¹ Pre-Harvest Interval (days).**STINK BUG, TARNISHED PLANT BUG**

Stink bugs feed on tomato fruit. Their piercing mouthparts sting the fruit, producing a yellowish blotch and corky tissue beneath the skin. Damaged fruit does not peel well during processing. Tarnished plant bug causes similar damage. Stink bugs often move into tomatoes from wheat fields or weedy areas as they dry out in mid-summer. See Table 9-113, *Tomato Insect Control Recommendations*, this page.

TOMATO OR TOBACCO HORNWORM

These hornworms are large, smooth, green caterpillars. Mature larvae measure 8 cm in length. The hornworm has seven or eight conspicuous white V-shaped markings down each side and a prominent spike (horn)

on its rear end. Hornworms feed on the leaves, stems and fruit of tomato plants.

If populations exceed one larvae per 30 plants, apply one of the products listed in Table 9-113, *Tomato Insect Control Recommendations*, this page.

CABBAGE LOOPER

The cabbage looper is a sporadic pest of tomatoes. Use a treatment threshold of 15 larvae per 30 plants. For complete identification and management information, see *Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar*, on page 91. Also see Table 9-113, *Tomato Insect Control Recommendations*, this page.

SAP BEETLES

Sap beetles are attracted to damaged or rotting fruit. Establish roadways or dedicated spray rows in the field at suitable intervals to minimize damage caused by farm equipment. Avoid crushing of fruit at picking time.

For processing crops, harvest as close as possible to time of delivery to the factory. If loaded wagons are not delivered immediately, leave them exposed to air circulation.

Birds

Bird-feeding damage on tomato fruit results in reduced yields and quality, as well as increased sorting costs. Noisemakers, such as propane cannons and digital distress calls may be successful deterrents. Use more than one type of scare device. Regular changes to the noise frequency pattern and distribution of these scare tactics will improve their efficacy. Start control measures early, before birds get accustomed to feeding in the field. See *Birds*, on page 64.

Overall population control is not feasible. Gulls, crows, cowbirds, starlings, grackles and blackbirds are protected under the *Wildlife Conservation Act*. However, growers may acquire a permit to use a firearm to scare or shoot birds causing damage to crops. For a permit, call the Permits Officer, Canadian Wildlife Service, Environment Canada, 905-336-4464.

Physiological Disorders**Blossom-End Rot (BER)**

Blossom-end rot is a localized calcium deficiency in the blossom end of the fruit. It occurs when dry soil conditions reduce the amount of water movement into the plant, thus reducing the movement of calcium to the fruit. Calcium is an important component of cell development. BER is caused primarily by dry soil conditions, not by a deficiency of calcium in the soil.

Side-dressing with calcium nitrate will not prevent BER if adequate moisture is not consistently available. Foliar sprays of calcium are also ineffective. Foliar-applied calcium is taken up and fixed in the leaves, and very little reaches the fruit. Avoid deep cultivation, which can prune roots and reduce water uptake. Blossom-end rot can be minimized by properly scheduled irrigation, ensuring steady movement of water and calcium into the plant. (See *Irrigation*, on page 27.)

Chemical Fruit Ripening

Ethephon (Ethrel) is used on processing tomatoes to trigger uniform ripening for once-over harvest. It will also enhance ripening in the late cultivars or during late seasons. For best results, apply ethephon to healthy fields. If plants are under moisture or disease stress, avoid the use of ethephon or apply it at reduced rates.

Ethephon is only effective on mature green fruit. Mature green fruit contain a gelatinous pulp surrounding the seeds. Apply when 5%–20% of the fruit are showing red colour development.

Good spray coverage on fruit and foliage is essential for maximum effectiveness. Use the higher label rates when day temperatures are below 18°C or when plant growth is dense. Excessive rates of ethephon will cause defoliation, reduce fruit quality and shorten field holding ability. Cool temperatures will delay colour development and extend the duration between treatment and harvest. Generally, fruit is ready to harvest 14–21 days after treatment.

Ethrel is not recommended for use on fresh-market tomatoes.

Harvest and Storage

Mature-green fresh-market tomatoes may be stored at 13°C–21°C for 1–3 weeks. Store firm, ripe tomatoes at 8°C–10°C for no more than 4–7 days. Maintain storage at a relative humidity of 90%–95%.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

After harvest is completed, seed a cover crop to protect soil and reduce erosion. In addition, the cover crop will absorb and tie up left-over nitrogen fertilizer, reducing leaching.

10. Using Pesticides in Ontario

Read the latest product label
before using a pesticide!

Review the Grower Pesticide
Safety Course Manual.

Keep detailed spray records.

Federal Registration of Pesticides

Before a pesticide can be sold or used in Ontario, it must be registered under the federal *Pest Control Products Act* (PCP Act) and be classified under the provincial *Pesticides Act*. The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticides for use in Canada following an evaluation of scientific data to ensure that the product has merit and value. It also ensures that the human health and environmental risks associated with its proposed use are acceptable.

The PMRA re-evaluates registered pesticides to determine whether today's health and environmental protection standards are still met when following the label directions. Outcomes of a re-evaluation can be:

- no change in the registration
- label amendments (i.e., changes to personal protective equipment requirements, re-entry intervals and buffer zones)
- modifications to existing maximum residue limits (MRLs)
- elimination or phasing-out of certain uses or formulations
- no further acceptance of the registration

The pesticide label is a legal document. It prescribes how the pesticide can be legally used. Off-label use is prohibited. It is against the law to use the pesticide in any other way or on any other crop or pest than as specified on the label. Labels for all registered pesticides are under Label Search on the PMRA website at www.pmr-arla.gc.ca. Ensure you have the most current label and are aware of any re-evaluation decisions.

Regulation of Pesticides in Ontario

The Ministry of the Environment (MOE) is responsible for regulating the sale, use, transportation, storage and

disposal of pesticides in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 63/09. All pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 63/09, which are available on the e-laws website at www.e-laws.gov.on.ca or by calling Service Ontario at 1-800-668-9938 or 416-326-5300.

Classification of Pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the MOE the classification of pesticide products before they can be sold or used in Ontario. Pesticide products are classified on the basis of their toxicity, environmental or health hazard, persistence of the active ingredient or its metabolites, concentration, usage, federal class and registration status. This classification system provides the basis for regulating the distribution, availability and use of pesticide products in Ontario. Once approved by the MOE, classified products are posted on the MOE website at www.ene.gov.on.ca.

The Ontario Classification is also included in Table 11-1, *Pesticides Used on Vegetable Crops in Ontario*, on page 221.

The Ontario pesticide classification system changed from 6 Schedules to 11 Classes (Regulation 63/09).

Certification and Licensing

Growers and Their Assistants

For information about certification for growers and training for assistants to growers, visit the Ontario Pesticide Education Program website at www.opecp.ca or call 1-800-652-8573.

Commercial Applicators (Exterminators) and their Assisting Technicians

For more information about exterminator licensing and technician training, visit the Ontario Pesticide Training & Certification website at www.ontariopesticide.com/OPTC/default.htm or call 1-888-620-9999 or 519-674-1575.

For more information about pesticide regulations, certification and licensing see:

- Inside front cover of this publication
- Pest Management Regulatory Agency (PMRA) website: www.pmr-arla.gc.ca
- PMRA Pest Management Information Service: 1-800-267-6315 (from within Canada) or 1-613-736-3799 (from outside Canada)
- Ontario Ministry of the Environment (MOE) website: www.ene.gov.on.ca
- Regional MOE Pesticides Specialist (See Appendix B, *Ontario Ministry of Environment — Regional Contact Information*, on page 234)
- Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) website: www.ontario.ca/omafra
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) website: www.opecp.ca
- Ontario Pesticide Training & Certification website: www.ontariopesticide.com/OTPC/default.htm

Pesticide Application Information

When you decide to use a pesticide, choose the most appropriate formulation and application method for your situation. Use only a properly calibrated sprayer. Choose less toxic alternatives when possible. Take all possible precautions to prevent the exposure of people and non-target organisms to the pesticide. Read the most current pesticide label thoroughly before application. The label provides important information, such as:

- directions for use (rates of application, crops it can be used on, target pests, crop rotation restrictions, total number of applications, droplet size/nozzle type, application equipment, timing and ideal weather conditions)
- required personal protective equipment
- health hazards and toxicity
- re-entry intervals
- buffer zones
- special warnings
- steps to be taken in case of an accident
- disposal

For more information on hazards, consult the Material Safety Data Sheet (MSDS) or contact the manufacturer.

Re-Entry Intervals

The re-entry interval, also referred to as Restricted Entry Interval (REI), is the period of time following a pesticide application during which workers must not enter the treatment area without wearing protective clothing and personal protective equipment. This allows any pesticide residue and vapours to dissipate from the treatment location (e.g., field), preventing the possibility of inadvertent pesticide exposure.

The PMRA reviews each pesticide to determine whether the label should include a specific re-entry interval. If the re-entry interval is not stated on the label, assume that the spray solution must be dry before re-entry can occur. Some pesticides have labels that carry a warning about working in treated crops. Follow the label recommendations.

See Table 11–3, *Re-Entry Intervals for Pesticides Used on Vegetable Crops*, on page 231.

Days to Harvest for Food Crops (Preharvest Intervals, Pregrazing and Feeding Intervals)

These intervals state the minimum time that must pass between the last pesticide application and the harvesting of the crop, or the grazing or cutting of the crop for livestock feed. If you harvest a crop before the preharvest interval (PHI) has passed, there may be pesticide residues in excess of the maximum residue limits (MRLs) set by PMRA.

Preharvest intervals for each product are listed in the insecticide and fungicide recommendation tables in Chapter 9, *Crop Management Recommendations*, starting on page 67.

To avoid exceeding the maximum residue limits, always follow the directions on the label.

Buffer Zones

Buffer zones are areas left untreated to protect an adjacent sensitive area, such as sensitive terrestrial and aquatic habitats, well heads, non-target crops and areas where children play.

Leave a suitable buffer zone between the treatment area and adjacent sensitive areas. Buffer zones may vary depending on the method of application (i.e., aerial, field boom, hand-held sprayer). Some pesticide labels specify buffer zone requirements. Check the pesticide label for the type of buffer zone required.

Sensitive terrestrial habitats include hedgerows, grasslands, shelterbelts, windbreaks, forested areas, woodlots, vegetative strips, etc.

Sensitive aquatic habitats include lakes, reservoirs, streams, creeks, ditches, marshes, wetlands, ponds, commercial fish ponds, etc.

Setback Distances for Water Bodies

It is an offence under the federal *Fisheries Act* to introduce into water any material that may be harmful to fish or fish habitat. To protect these waters, applicators must determine a suitable setback distance between the area to be protected and the area where pesticide treatments are planned (if one is not specified on the pesticide label). The protected area includes the water body as well as adjacent riparian (riverbank) areas that contribute to fish food and habitat.

Protect the Environment

Protect Water Sources

According to the British Crop Protection Council (BCPC), between 40% and 70% of surface water pesticide contamination comes from mixing and filling areas.

You should load or mix pesticides on impermeable surfaces that are safely away from watercourses or environmentally sensitive areas. Drainage and run-off should be collected and disposed of safely (*Your Guide to Using Pesticides*, BCPC 2007).

Clean your spray equipment away from wells, ponds, streams and ditches. Apply the diluted rinse water (usually at a ratio of 10 to 1) to the treatment area (crop) but do not exceed the pesticide rate recommended on the label.

Do not make a direct connection between any water supply (e.g., public supply, wells, watercourse or pond) and a spray tank. Use an anti-backflow device or intermediate system to prevent back-siphoning that could contaminate the water supply.

Immediately contain and clean up any spills to prevent contamination to water sources.

Check the pesticide label for specific instructions on water source protection.

For more information on protecting water sources, see:

- OMAFRA Factsheet *Groundwater – An Important Rural Resource: Protecting the Quality of Groundwater Supplies*, Order No. 06-115
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13

Prevent Bee Poisoning

It is important to protect bees when spraying insecticides. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees sources of nectar for honey production.

Read each pesticide label for specific precautions regarding bees. Choose less toxic alternatives when possible. Most organophosphate and carbamate insecticides are highly toxic to bees.

Advise local beekeepers before you apply a pesticide, so that they may take additional precautions to protect their bees. Contact the Provincial Apiarist at 1-888-466-2372, ext. 63595, for a list of the beekeepers in your area. Follow guidelines regarding spray timing to prevent unnecessary poisonings. For more information on preventing bee poisoning, see the "apiculture" section of the OMAFRA website at www.ontario.ca/crops.

See Table 7-1, *Relative Toxicity of Insecticides to Honeybees*, on page 53.

Manage Drift

- Do not spray when wind speeds are high or gusty. These conditions will favour spray drift. Check pesticide labels for allowable wind speeds for spraying applications. Some labels may not provide this specific information. Constantly monitor wind conditions during spraying using a good quality wind meter. Record the wind speed and direction. As wind conditions change, you may need to make adjustments to further reduce the drift potential, such as adjusting water volume upwards, minimizing nozzle-to-target distance, changing nozzle technology, changing fields because of surrounding influences or stop spraying until conditions improve.
- Do not spray during periods of dead calm. Periods of dead calm usually occur in early morning or late evening, at which time the temperature is usually cooler and the relative humidity is typically higher. The combination of these factors can result in drift-sized droplets staying in the field. When the wind

picks up, these spray droplets can move away from the target area, possibly causing injury to adjacent non-target areas.

- Use the recommended sprayer output (water volume).
- Use a nozzle that will produce the appropriate droplet size if specified on the pesticide label.
- Use the most appropriate nozzle for the type of application. Where practical, use air induction/venturi nozzles, which significantly reduce drift when compared to conventional nozzles.
- Check the height of the boom to the target and minimize the distance as much as possible while still maintaining spray uniformity.
- Follow buffer zone requirements for the protection of adjacent sensitive areas as outlined on the pesticide label.
- Use spray plume protection where practical or available (hoods, shrouds, screens and air curtains).
- Use drift-reducing adjuvants in the spray tank as directed on the label.
- Use wick weeders instead of spraying when possible.
- Use non-volatile pesticide formulations or products.

For more information about spray drift, see:

- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) videos *How to Manage Spray Drift* and *Spray Drift Reduction Through Air Induction*, available at www.opep.ca/Educational/EducationalMaterials.htm

Pesticide Disposal

Empty Pesticide Containers

Never reuse empty containers. Puncture the cleaned empty containers to make them unusable.

The Ontario Empty Pesticide Container Recycling Program is available to growers and commercial applicators. Through this program, you can return cleaned and triple rinsed plastic/metal pesticide containers (up to 23 L for plastic and 20 L for metal) to pesticide container depots located throughout the province. Remove the paper booklet from the pesticide container before recycling. To locate the closest pesticide container recycling depot, call the Ontario Pesticide Education Program at 1-800-652-8573,

your local dealer or municipality, or visit the CropLife Canada website at www.croplife.ca.

Surplus Spray Mix

The best way to dispose of any excess spray mix is to find other fields that require an application of this pesticide. Before spraying, check the label to make sure the pesticide is registered for use on that crop.

If you cannot find another field to spray, dilute the remaining spray mix by adding 10 parts of water for each 1 part of spray mix. The diluted solution can be safely applied to the original treated area as long as you do not exceed the pesticide rate recommended on the label. Be sure to check the label for any restrictions about crop rotation, days to harvest or surplus spray mix disposal.

Never re-spray the treated field with undiluted spray mix. Spraying an area twice will double the recommended pesticide rate. This may cause illegal pesticide residues in the harvested crop or harmful residues in the soil that can cause crop damage.

Surplus Pesticides in Storage

Be sure to safely dispose of pesticides that you do not need or cannot use. Options for proper disposal include:

- Contact the supplier. It is sometimes possible to return unused pesticide if it is still in its original, unopened container.
- Hire a waste hauler who is licensed under Part V of the *Environmental Protection Act* to carry hazardous wastes. Look in the Yellow Pages of your telephone directory under Liquid Waste Removal.
- Check your local paper or visit the CropLife Canada website (www.croplife.ca) for upcoming Obsolete Pesticide Collection Days.
- Contact your municipality to see if any waste collection days are scheduled and verify whether quantities of agricultural pesticides will be accepted.

Storing Pesticides

Ontario's *Pesticides Act* and Regulation 63/09 provide details on storage requirements for storage facilities. The storage requirements that must be followed are dependent on which classes of pesticides you store.

For more information about storing pesticides, see:

- OMAFRA Factsheet, *Farm Pesticide Storage Facility*, Order No. 07-059
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) Grower Pesticide Safety Course Manual, available at www.opep.ca/Educational/EducationalMaterials.htm

Pesticide Spills

If a pesticide spill causes, or is likely to cause, an adverse effect that is greater than that which would result from the proper use of the pesticide, you must notify the **Ministry of the Environment Spills Action Centre at 1-800-268-6060** (24 hours a day, 7 days a week) and your municipality.

A spill is defined as a discharge of pollutant that is abnormal in quality or quantity, from or out of a structure, vehicle, or other container into the environment. An incident such as an overturned pesticide sprayer that results in the loss of the spray solution to the environment, is an example of a spill. A pesticide container that ruptures and leaks its contents is another example of a spill. The discharge or spraying of a pesticide in an unapproved area, commonly referred to as an overspray, is also considered a spill.

Before you begin to clean up a spill of any nature, remember to protect yourself against pesticide exposure. Wear the proper protective clothing and personal protective equipment. If the spill occurs inside an enclosed area (e.g., a pesticide storage area

or a vehicle during transport), ventilate the area first. Once you have protected and/or removed yourself and other persons or animals from the spill site, take additional measures to stop the spill at the source and prevent it from spreading and/or contaminating watercourses. Specific precautions, emergency contact information and first aid procedures may be found on the label.

For minor spills, it may be possible to remediate the problem:

- **For a liquid spill** – Cover the spill with a thick layer of absorbent material such as kitty litter, vermiculite or dry soil. Sweep or shovel the material into a waste drum and dispose of the contents as you would a hazardous waste.
- **For a dust, granular or powder spill** – Sweep or shovel the material into a waste drum and dispose of the contents as you would a hazardous waste.

For major spills, it is essential to stop the spill from spreading. The cleanup guidelines above may not be appropriate for all spill situations. Once you have contained the spill, follow directions from the manufacturer and regulatory authorities on cleaning the contaminated area.

For information on preventing spills, see:

- OMAFRA Factsheet, *Ways to Avoid Pesticide Spills*, Order No. 96-025
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) Grower Pesticide Safety Course Manual, available at www.opep.ca/Educational/EducationalMaterials.htm

For pesticide poisonings and pesticide injuries call:

Poison Information Centre:

1-800-268-9017

(TTY) 1-877-750-2233

For more information, see inside back cover on Emergency and First Aid Procedures for Pesticide Poisoning.

11. Pesticides Used on Vegetable Crops in Ontario

Table 11-1. Pesticides Used on Vegetable Crops in Ontario

Table 11-1. Pesticides Used on Vegetable Crops in Ontario											
Use Codes: a – acaricide n – nematocide		b – bactericide pgr – plant growth regulator		f – fungicide r – rodenticide		h – herbicide s – seed treatment		i – insecticide v – vine killing		m – miticide	
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations					Company or Agent's Code	
1,3 dichlorpropene	See TELONE II										
1,3 dichlorpropene + chloropicrin	See TELONE C-17										
abamectin	See AGRI-MEK										
acephate	See ORTHENE										
acetamiprid	See ASSAIL										
ACROBAT 50 WP	dimethomorph	f	50	3	potatoes					ENG	
ACTARA 240SC	thiamethoxam	i	240 g/L	3	potatoes					SYZ	
ACTARA 25 WG	thiamethoxam	i	25	4	potatoes					SYZ	
ACTIVOL	gibberellic acid	pgr	0.92 g/tablet	4	rhubarb					NRA	
ADMIRE 240 F	imidacloprid	i	240 g/L	4	brassica crops, cucurbits (vine crops) eggplant, lettuce, potatoes, sweet potatoes, tomatoes					BCZ	
ADMIRE 240 SPT	imidacloprid	i	240 g/L	4	potato seed piece					BCZ	
AGRI-MEK 1.9% EC	abamectin	i	19 g/L	3	celery, potatoes					SYZ	
AGROX B-2	diazinon + captan	s	11 + 33.5	3	beans, peas, sweet corn					NRA	
AGROX CD	diazinon + captan	s	15 + 15	3	beans, peas, sweet corn					NRA	
ALIAS 240 SC	imidacloprid	i	240 g/L	4	lettuce (field), potatoes, sweet potatoes, tomatoes					UAG	
ALIETTE WDG	fosetyl-al	f	80	3	lettuce, onions, broccoli, bok choy, rutabagas					BCZ	
ALLEGIANCE FL	metalaxyl	s	317 g/L	3	beans, peas, sugarbeets, sweet corn					BCZ	
ALLEGRO 500 F	fluzinam	f	500 g/L	3	beans, brassica crops, potato					ISK	
AMBUSH 500 EC	permethrin	i	500 g/L	4	asparagus, beans, brassica crops, carrots, lettuce, onions, peas, peppers, potatoes, radishes, sugarbeets, sweet corn, tomatoes					ENG	
APRON FL	metalaxyl	s	317 g/L	3	beans, peas, sugarbeets, sweet corn					BCZ	
APRON MAXX RFC	metalaxyl-M + fludioxonil	s	1.1 + 0.73	3	beans, peas					SYZ	
APRON XL LS	metalaxyl-M	s	33.3	3	beans, beets (table), brassica crops, carrots, cucurbits (vine crops), eggplant, leafy greens, lettuce, onions, peas, peppers, rutabagas, spinach, sugarbeets, sweet corn, tomatoes					SYZ	
ASSAIL 70 WP	acetamiprid	i	70	4	brassica crops, celery, lettuce, endive, parsley, spinach, Swiss chard, leafy greens (see label), peppers, potatoes, rhubarb, tomatoes					DUQ	
azoxystrobin	See QUADRI, DYNASTY										
Bacillus subtilis	See SERENADE										
Bacillus thuringiensis	See NOVODOR, DIPEL, THURICIDE, BIOPROTEC										

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Class 2: Restricted – commercial use only; very hazardous and/or persistent

Class 3: Restricted – commercial use only; moderately hazardous and/or moderately persistent

Class 4: Restricted – commercial use only; low hazard and/or low persistence

Table 11–1. Pesticides Used on Vegetable Crops in Ontario

Use Codes: a – acaricide b – bactericide f – fungicide h – herbicide i – insecticide m – miticide n – nematocide pgr – plant growth regulator r – rodenticide s – seed treatment v – vine killing						
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations	Company or Agent's Code
BASAMID GRANULAR	dazomet	n	97	3	pre-plant site preparation	BAZ
BIOPROTEC CAF	<i>Bacillus thuringiensis</i>	i	11,400 IU/ mg	3	beans (snap), brassica crops, herbs, sweet corn, tomatoes, transplants (tomato and pepper)	AFG
BOTRAN 75 W	dichloran	f	75	4	beans, garlic, lettuce	GOW
<i>boscalid</i>	See LANCE					
BRAVO 500	chlorothalonil	f	500 g/L	4	asparagus, broccoli, Brussels sprouts, cabbage, cauliflower, carrots, celery, cucurbits (vine crops), onions, parsnips, potatoes, sweet corn, tomatoes	SYZ
BUMPER 418 EC	propiconazole	f	418 g/L	3	sweet corn	UAG
BUSAN 1020	metam sodium	h, f, n	33	4	non-crop areas	BUL
BUSAN 1180	metam potassium	n	54	3	pre-plant site preparation	BUL
BUSAN 1236	metam sodium	h, f, n	42.5	4	pre-plant site preparation	BUL
CABRIO EG	pyraclostrobin	f	20	4	beets (table), carrots, cucurbits (vine crops), eggplant, garlic, horseradish, onions, peppers, radish, rutabaga, tomatoes	BAZ
<i>captan</i>	See MAESTRO, SUPRA CAPTAN					
<i>carbaryl</i>	See SEVIN XLR					
<i>carbathiin-thiram</i>	See PRO-GRO, VITAFLO					
<i>chlorantraniliprole</i>	See CORAGEN					
<i>chloropicrin</i>	See CHLOROPICRIN, PIC PLUS					
CHLOROPICRIN 100	chloropicrin	n	99	2	peppers, potatoes, tomatoes	HND
<i>chlorothalonil</i>	See BRAVO					
<i>chlorpyrifos</i>	See LORSBAN, PYRIFOS, PYRINEX					
CITATION 75WP	cyromazine	i	75	3	brassica leafy greens (see label), celery, lettuce, leafy greens (see label), parsley, spinach, Swiss chard	SYZ
<i>clothianadin</i>	See PONCHO, TITAN, CLUTCH					
CLUTCH	clothianidin	i	50	2	potatoes	ENG
COPPER 53 W	copper sulfate	f	53	3	beets (table), broccoli, Brussels sprouts, cabbage, cauliflower, celery, cucurbits (vine crops), potatoes	UAG
<i>copper hydroxide</i>	See PARASOL, KOCIDE					
<i>copper oxychloride</i>	See COPPER SPRAY					
COPPER SPRAY	copper oxychloride	f	50	4	celery, cucurbits (vine crops), potatoes	UAG
<i>copper sulfate</i>	See COPPER 53W					
CORAGEN 200 SC	chlorantraniliprole	i	200 g/L	2	brassica crops, leafy greens (see label), potatoes, tomatoes	DUQ
COUNTER 15 G	terbufos	i	15	2	sugarbeets	AMV
CRUISER 5FS	thiamethoxam	s	47.6	3	beans, peas, sweet corn	SYZ
CRUISER MAXX BEANS	thiamethoxam + fludioxonil + metalaxyl-M	s	22.6 + 1.7 + 1.12	3	peas	SYZ
CURZATE 60 DF	cymoxanil	f	60	3	potatoes	DUQ

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Table 11-1. Pesticides Used on Vegetable Crops in Ontario

Table 11-1. Pesticides Used in Vegetable Crop Production									
Use Codes:		a – acaricide n – nematocide	b – bactericide pgr – plant growth regulator	f – fungicide r – rodenticide	h – herbicide s – seed treatment	i – insecticide v – vine killing	m – miticide		
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations				Company or Agent's Code
cyazofamid	See RANMAN								
CYDON 480	dimethoate	i	480 g/L	3	asparagus, beans, beets (table), broccoli, Brussels sprouts, cauliflower, Chinese broccoli, Chinese cabbage, pak choy, eggplant, lettuce, peas, peppers, potatoes, Swiss chard, tomatoes				BAT, CAU
cymoxanil	See CURZATE								
cypermethrin	See RIPCORDER, UP-CYDE								
cyprodinil + fludioxonil	See SWITCH								
cyromazine	See GOVERNOR, CITATION								
dazomet	See BASAMID								
DCT	diazinon + captan + thiophanate-methyl	s	6 + 18 + 14	4	sweet corn				NRA
DECIS 5 EC	deltamethrin	i	50 g/L	3	asparagus, broccoli, Brussels sprouts, cabbage, cauliflower, kale, onions, peppers, potatoes, sweet corn, tomatoes				BCZ
DEGREE 50 WDG	fenhexamid	f	50	3	tomato transplants (greenhouse)				AVV
DELEGATE WG	spinetoram	i	25	3	asparagus, brassica crops, carrots, leafy vegetables, radish, rutabagas, tomatoes				DWE
deltamethrin	See DECIS								
DES-I-CATE	endothall	v	62 g/L	n/a	potatoes				UPI
diazinon	See DIAZINON								
diazinon + captan	See AGROX								
diazinon + captan + thiophanate-methyl	See DCT								
DIAZINON 50 W	diazinon	i	50	3	carrots, onions, parsnips, peppers, radishes, spinach, Swiss chard, tomatoes				UAG
DIAZINON 500 E	diazinon	i	500 g/L	3	beets (table), lettuce, onions, parsley, parsnips, radishes, spinach, Swiss chard, tomatoes				UAG
DIBROM	naled	i	864 g/L	3	beans (lima), broccoli, Brussels sprouts, cabbage, cauliflower, kale, mustard greens, celery, lettuce, endive, onions, peas, potatoes, spinach, sugarbeets, tomatoes				UAG
dichloran	See BOTRAN								
dicofof	See KELTHANE								
difenoconazole + methalaxyl-M	See DIVIDEND								
dimethoate	See CYGON, LAGON								
dimethomorph	See ACROBAT								
DIPEL 2X DF	Bacillus thuringiensis	i	32,000/mg	4	brassica crops, herbs, lettuce, parsley, spinach, sweet corn, tomatoes				VBC
diquat	See REGLONE								
DITHANE DG	mancozeb	f	75	4	carrots, celery, cucurbits (vine crops), dry onions, potatoes, tomatoes				DWE

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Table 11-1. Pesticides Used on Vegetable Crops in Ontario

Use Codes:	a – acaricide n – nematocide	b – bactericide pgr – plant growth regulator	f – fungicide r – rodenticide	h – herbicide s – seed treatment	i – insecticide v – vine killing	m – miticide
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations	Company or Agent's Code
DITHANE F-45	mancozeb	f	37	4	seed potatoes (post harvest)	DWE
DIVIDEND XL RTA	difenoconazole + metalaxyl-M	s	3.37 + 0.27	3	sweet corn	SYZ
DYNASTY 100 FS	azoxystrobin	s *	100 g/L	3	sweet corn	SYZ
endosulfan	See THIODAN, THIONEX					
endothall	See DES-I-CATE					
ENFUSE	metam sodium	h, f, n	41.98	4	pre-plant site preparation	ENG
ENTRUST 80W	spinosad	i	80	3	beans, brassica crops, eggplant, lettuce, endive, leafy greens, peppers, potatoes, radishes, rhubarb, rutabagas, turnips, spinach, Swiss chard, sweet corn, tomatoes	DWE
FALGRO	gibberellic acid	pgr	1 g/tablet	4	potatoes	NRA
famoxadone + cymoxanil	See TANOS					
fenamidone	See REASON					
fenhexamid	See DECREE					
FERBAM 76 WDG	ferbam	f	76	4	transplant lettuce	UAG
ferric phosphate	See SLUGGO					
fluazinam	See ALLEGRO					
fludioxonil	See MAXIM					
fludioxonil + metalaxyl-M	See MAXIM XL					
FORCE 3.0 G	tefluthrin	i	3	3	sweet corn	SYZ
fosetyl-al	See ALIETTE					
FULFILL 50 WG	pymetrozine	i	50	3	potatoes	SYZ
GAUCHO 480 FL	imidacloprid	s	480 g/L	2	beans, sweet corn	BCZ
GAVEL 75 DF	zoxamide + mancozeb	f	8.4 + 66.7	4	potatoes	GOW
gibberellic acid	See ACTIVOL, FALGRO					
Gliocladium catenulatum	See PRESTOP					
glufosinate ammonium	See IGNITE					
GOVERNOR 75 WP	cyromazine	s	75	2	imported onion seed	SYZ
GRAPPLE	imidacloprid	i	240 g/L	4	brassica crops, cucurbits (vine crops) eggplant, lettuce, potatoes, sweet potatoes, tomatoes	CAU
HEADLINE EC	pyraclostrobin	f	250 g/L	3	beans, peas, potatoes, sugarbeets, sweet corn	BAZ
hydrogen peroxide	See STOROX					
IGNITE 15 SN	glufosinate ammonium	v	150 g/L	4	potatoes	BCZ
imidacloprid	See ADMIRE, GAUCHO, ALIAS, GRAPPLE					
IMIDAN 50 WP	phosmet	i	50	4	carrots, celery	GOW
iprodione	See ROVRAL					
kaolin clay	See SURROUND					

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Table 11-1. Pesticides Used on Vegetable Crops in Ontario

Use Codes: a – acaricide n – nematocide		b – bactericide pgr – plant growth regulator		f – fungicide r – rodenticide		h – herbicide s – seed treatment		i – insecticide v – vine killing		m – miticide	
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations					Company or Agent's Code	
KELTHANE 50 W	dicofol	m	51	3	beans, cucurbits (vine crops)					DWE	
KOCIDE 2000	copper hydroxide	f, s	61.4	3	beans, peppers (field and transplants), potatoes, tomatoes (field and transplants)					DUQ	
LAGON 480	dimethoate	i	480 g/L	3	asparagus, beans, broccoli, Brussels sprouts, cauliflower, kale, Chinese broccoli, eggplant, lettuce, peas, peppers, potatoes, Swiss chard, tomatoes					UAG	
lambda-cyhalothrin		See MATADOR, SILENCER									
LANCE WDG	boscalid	f	70	2	beans (snap and lima), carrots, cucurbits (vine crops) eggplant, lettuce, onions, peas, peppers, potatoes, tomatoes					BAZ	
LANNATE TNG	methomyl	i	90	2	beans, broccoli, Brussels sprouts, cabbage, cauliflower, head lettuce, peas, sweet corn, tomatoes					DUQ	
LORSBAN 15G	chlorpyrifos	i	15	4	broccoli, Brussels sprouts, cabbage, cauliflower, onions, rutabaga					DWE	
LORSBAN 4E	chlorpyrifos	i	480 g/L	3	carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, Chinese cabbage, pak choy, cucumber, garlic, onions (dry), radishes, peppers, potatoes, rutabagas, sugarbeets, sweet corn					DWE	
LORSBAN 50W	chlorpyrifos	i	50	3	cabbage					DWE	
MAESTRO 80 DF	captan	f	80	3	cucumber, tomatoes, vegetable transplants in greenhouse (crucifer, eggplant, pepper, tomatoes, celery)					AVV	
MALATHION 25W	malathion	i	25	4	asparagus, beets (table), cucurbits (vine crops), peas, spinach, tomatoes					UAG	
MALATHION 500 E	malathion	i	500 g/L	4	asparagus, beans, beets (table), celery, cucurbits (vine crops), garlic, lettuce, peas, peppers, radishes, sugarbeets, tomatoes					UAG	
maleic hydrazide		See ROYAL MH 60									
mancozeb		See DITHANE, TUBERSEAL, POTATO ST, PENNCOZEB, MANZATE PRO-STICK									
mandipropamid		See REVUS									
MANZATE PRO-STICK	mancozeb	f	75	3	carrots, celery, cucurbits (vine crops), onions (dry), potatoes, sugarbeets, tomatoes					DUQ	
MATADOR 120 EC	lambda-cyhalothrin	i	120 g/L	2	asparagus, beans, broccoli, Brussels sprouts, cabbage, cauliflower, garlic, leeks, lettuce, onions, peas, potatoes, sweet corn, sweet potatoes, tomatoes					SYZ	
MAXIM 480 FS	fludioxonil	s	40.3	3	beets (table), cauliflower, herbs, sugarbeets, sweet corn					SYZ	
MAXIM MZ PSP	fludioxonil + mancozeb	s	0.5 + 5.7	3	potato seed piece					SYZ	
MAXIM PSP	fludioxonil	s	0.5	3	potato seed piece					SYZ	
MAXIM LIQUID PSP	fludioxonil	f	40.3	3	potato seed piece					SYZ	
MAXIM XL	fludioxonil + metalaxyl-M	s	21 + 8.4	3	sweet corn					SYZ	
metalaxyl		See RIDOMIL, APRON, ALLEGIANCE									
metalaxyl-M		See RIDOMIL GOLD, APRON XL LS									
metalaxyl-M + chlorothalonil		See RIDOMIL GOLD + BRAVO									

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Table 11–1. Pesticides Used on Vegetable Crops in Ontario

Table 11-1. Pesticides Used on Vegetable Crops in Ontario											
Use Codes: a – acaricide n – nematocide		b – bactericide pgr – plant growth regulator		f – fungicide r – rodenticide		h – herbicide s – seed treatment		i – insecticide v – vine killing		m – miticide	
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations					Company or Agent's Code	
metalaxyl-M + mancozeb	See RIDOMIL GOLD MZ										
metalaxyl-M + fludioxonil	See APRON MAXX										
metam potassium	See BUSAN 1180										
metam sodium	See BUSAN, VAPAM, ENFUSE										
methamidophos	See MONITOR										
methomyl	See LANNATE TNG										
metiram	See POLYRAM										
MICROSCOPIC SULPHUR	sulphur	f	92	4	rutabagas					UAG	
MILSTOP	potassium bicarbonate	f	85	1	cucurbits (vine crops), peppers					BWI	
mineral oil	See SUPERIOR OIL										
MISSION 418 EC	propiconazole	f	418 g/L	3	asparagus, rutabagas					UAP	
MONITOR 480	methamidophos	i	480 g/L	2	broccoli, Brussels sprouts, cabbage, cauliflower, head lettuce, potatoes					AVV/ BCZ	
MOVENTO 240 SC	spirotetramat	i	240 g/L	4	brassica crops, celery, cucurbits (vine crops), eggplant, lettuce, peppers, rhubarb, spinach, sweet potatoes, tomatoes					BCZ	
myclobutanil	See NOVA										
naled	See DIBROM										
NO-DAMP	oxine benzoate	f	3.2	4	vegetable seedlings in greenhouse					PLG	
NOVA 40W	myclobutanil	f	40	3	asparagus					DWE	
novaluron	See RIMON										
NOVODOR	<i>Bacillus thuringiensis</i>	i	18,000/g	4	potatoes, tomatoes					VBC	
OBERON	spiromesifen	i/m	240 g/L	3	brassica crops, cucurbits (vine crops), eggplant, leafy vegetables, sweet potatoes, tomatoes,					BCZ	
OPAL INSECTICIDAL SOAP	potassium salts of fatty acids	i	47	4	herbs					OMD	
ORTHENE 75 SP	acephate	i	75	3	celery, Brussels sprouts, cabbage, cauliflower, head lettuce, peppers, potatoes, sweet corn, tomatoes					AVV	
oxamyl	See VYDATE										
oxine benzoate	See NO-DAMP										
PARASOL FLOWABLE	copper hydroxide	f	24.4	4	beans, cucumbers, peppers, potatoes, tomatoes					NUA	
PARASOL WP	copper hydroxide	f	50	3	sugarbeets					NUA	
PENNCOZEB 80 WP	mancozeb	f	80	4	carrots, celery, cucurbits (vine crops), onions (dry), potatoes, sugarbeets, tomatoes					ISK	
permethrin	See POUNCE, PERM-UP, AMBUSH										
PERM-UP	permethrin	i	384 g/L	3	asparagus, beans, beets, carrots, brassica crops, lettuce, onions, peas, peppers, potatoes, sugarbeets, sweet corn, tomatoes					UPI	
phosmet	See IMIDAN										
PIC PLUS	chloropicrin	n	85.1	2	tomatoes, peppers, potatoes					HND	
POLYRAM 16 D	metiram	s	16	4	potato seed piece					BAZ	

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Use Codes: a – acaricide n – nematocide		b – bactericide pgr – plant growth regulator		f – fungicide r – rodenticide		h – herbicide s – seed treatment		i – insecticide v – vine killing		m – miticide	
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations					Company or Agent's Code	
POLYRAM DF	metiram	f	80	4	asparagus, carrots, celery, potatoes, sugarbeets, tomatoes					BAZ	
PONCHO 600	clothianadin	s	48	2	sweet corn					BCZ	
POTATO ST16	mancozeb	s	16	4	potato seed piece					UAG	
potassium bicarbonate		See MILSTOP									
potassium salts of fatty acids		See OPAL INSECTICIDAL SOAP, SAFER'S TROUNCE									
POUNCE 384 EC	permethrin	i	384 g/L	4	asparagus, beans, beets (table) carrots, broccoli, Brussels sprouts, cabbage, cauliflower, pak choy, Chinese cabbage, horseradish, lettuce, onions, peas, peppers, potatoes, radishes, rutabagas, sweet corn, tomatoes					UAG/ BCZ	
PRESTOP	<i>Gliocladium catenulatum</i>		2 x 108 colony-forming units/g	3	greenhouse herb transplants (oregano, basil, parsley, thyme, dill)					PLG	
PRISTINE WG	pyraclostrobin + boscalid	f	25.2 + 12.8	2	carrots, celery, chives, garlic, onions, leeks, shallots, spinach					ENG	
PRO-GRO	carbathiin + thiram	s	30 + 50	4	onions					CRE	
propamocarb + chlorothalonil		See TATTOO C									
propiconazole		See BUMPER, MISSION, TOPAS, TILT									
pyraclostrobin		See CABRIO, HEADLINE									
pyraclostrobin + boscalid		See PRISTINE									
PYRIFOS 15G	chlorpyrifos	i	15	3	broccoli, Brussels sprouts, cabbage, cauliflower, onions					UAG	
pyrimethanil		See SCALA									
PYRINEX 480 EC	chlorpyrifos	i	480 g/L	3	carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, Chinese broccoli, Asian radish, cucumbers, garlic, onions (dry), peppers, potatoes, radish, rutabaga, sweet corn					UAG	
pyrimetozine		See FULFILL									
QUADRI FLOWABLE	azoxystrobin	f	250 g/L	3	beets (table), carrots, horseradish, potatoes, radishes, rutabagas/turnips, spinach, sugarbeets, sweet corn, tomatoes					SYZ	
QUINTOZENE 75 WP	quintozone	f	75	4	broccoli, Brussels sprouts, cabbage, cauliflower					PLG	
RANMAN 400 SC	cyazofamid	f	34.5	4	carrots, cucurbits (vine crops), potatoes					ISK	
REASON 500 SC	fenamidone	f	500 g/L	2	potatoes					BCZ	
REGLONE	diquat	v	240 g/L	4	potatoes					SYZ	
REVUS	mandipropamid	f	23.3	3	brassica crops, garlic, lettuce, leeks, onions, pepper (transplants), potatoes, spinach, tomatoes					SYZ	
RIDOMIL GOLD 1G	metalaxyl	f	2	3	carrots, lettuce					SYZ	
RIDOMIL GOLD 480 EC	metalaxyl-M	f	480 g/L	3	snap bean, potatoes					SYZ	
RIDOMIL GOLD MZ 68 WP	metalaxyl-M + mancozeb	f	4 + 64	3	lettuce (head), onions, potatoes					SYZ	
RIDOMIL GOLD + BRAVO twin pak	metalaxyl-M + chlorothalonil	f	480 + 500 g/L	3	potatoes					SYZ	

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² The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the MOE the classification of pesticide products before they can be sold or used in Ontario. Most pesticides used in vegetable crops are either a Class 2, 3 or 4. Users of these products must be certified through the Grower Pesticide Safety Course.

Class 2: Restricted – commercial use only; very hazardous and/or persistent

Class 3: Restricted – commercial use only; moderately hazardous and/or moderately persistent

Class 4: Restricted – commercial use only; low hazard and/or low persistence

Table 11-1. Pesticides Used on Vegetable Crops in Ontario

Use Codes: a – acaricide n – nematocidal		b – bactericide pgr – plant growth regulator		f – fungicide r – rodenticide		h – herbicide s – seed treatment		i – insecticide v – vine killing		m – miticide	
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations					Company or Agent's Code	
RIMON 10 EC	novaluron	i	10	2	potatoes					UAG	
RIPCORD 400 EC	cypermethrin	i	407 g/L	3	asparagus, carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, lettuce, onions, potatoes, rutabagas, sweet corn, tomatoes					BAZ	
RONILAN EG	vinclozolin	f	50	4	beans, lettuce					BAZ	
ROVRAL	iprodione	f	50 g/kg	3	beans, cabbage, cauliflower, garlic, leeks, lettuce, onions, carrots (imported seed)					BCZ	
ROYAL MH 60 SG	maleic hydrazide	pgr	60	4	dry onions, potatoes					CRE	
SAFER'S TROUNCE	potassium salts of fatty acids + pyrethrins	i	20 + 0.2	4	herbs					SFR	
SCALA SC	pyrimethanil	f	480 g/L	2	potatoes					BCZ	
SENATOR 70WP	thiophanate-methyl	f	70	4	sugarbeets					ENG	
SENATOR PSPT	thiophanate-methyl	s	10	4	potatoes (seed piece)					ENG	
SEVIN XLR	carbaryl	i	480 g/L	3	asparagus, beans, brassica crops, carrots, celery, cucurbits (vine crops), eggplant, lettuce, leafy greens, peppers, radishes, rutabagas, sweet corn, tomatoes					BCZ	
SERENADE MAX	<i>Bacillus subtilis</i>	f	14.6	4	celery, garlic, lettuce, onions					UAG	
SERENADE ASO	<i>Bacillus subtilis</i>	f	1.34	4	beets (table), brassica crops, carrots, chives, cucurbit crops (vine crops), eggplant, garlic, onions, leafy vegetables, leeks, peppers, potatoes, radishes, rutabagas, spinach, sweet potatoes, tomatoes					UAG	
SILENCER 120 EC	lambda-cyhalothrin	i	120 g/L	2	asparagus, beans, broccoli, Brussels sprouts, cabbage, cauliflower, garlic, lettuce, onions, peas, potatoes, sweet corn, sweet potatoes, tomatoes					UAG	
SLUGGO	ferric phosphate	i	0.76	4	beans, brassica crops, peas, sweet corn					ENG	
spinetoram	See DELEGATE										
spinosad	See SUCCESS, ENTRUST										
spiromesifen	See OBERON										
spirotriamat	See MOVENTO										
STOROX	hydrogen peroxide	f	27	2	potatoes, sweet potatoes					BIB	
SUCCESS 480 SC	spinosad	i	480 g/L	4	beans (snap), brassica crops, celery, eggplant, lettuce, leafy greens, peppers, potatoes, radishes, rhubarb, rutabagas, spinach, Swiss chard, sweet corn, tomatoes					DWE	
sulphur	See MICROSCOPIC SULPHUR										
SUPERIOR OIL 70	mineral oil	a, i	99	4	rutabagas					UAG	
SUPRA CAPTAN 80 WDG	captan	f	80	3	cucumbers, tomatoes, vegetable transplants in greenhouse (brassica crops, eggplant, peppers, tomatoes, celery)					UAG	
SURROUND WP	kaolin clay	i	95	4	carrots, celery, cucurbits (vine crops), lettuce, parsley, potatoes					ENG	
SWITCH 62.5 WG	cyprodinil + fludioxonil	f	37.5 + 25	3	beans, cabbage, carrots, mustard/turnip greens, onions					ENG	

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Table 11-1. Pesticides Used on Vegetable Crops in Ontario

Use Codes:	a – acaricide n – nematocide	b – bactericide pgr – plant growth regulator	f – fungicide r – rodenticide	h – herbicide s – seed treatment	i – insecticide v – vine killing	m – miticide
Examples of Brand Name/ Trade Name ¹	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule ²	Crop Recommended Registrations	Company or Agent's Code
TANOS 50 DF	famoxadone + cymoxanil	f	25 + 25	3	potatoes, tomatoes	DUQ
TATTOO C	propamocarb + chlorothalonil	f	375 g/L + 375 g/L	3	potatoes, cucurbits (vine crops)	BCZ
tefluthrin	See FORCE					
TELONE C-17	1,3 dichloropropene + chloropicrin	n,f	78 + 16.5	3	pre-plant site preparation	DWE
TELONE II	1,3 dichloropropene	n	97.5	3	pre-plant site preparation	DWE
terbufos	See COUNTER					
thiamethoxam	See ACTARA, CRUISER					
THIODAN 4 EC	endosulfan	i	400 g/L	3	beans, broccoli, Brussels sprouts, cabbage, cauliflower, celery, cucurbits (vine crops), eggplant, head lettuce, peas, peppers, potatoes, rutabagas, spinach, tomatoes	BCZ
THIODAN 50 WP	endosulfan	i	50	3	celery, broccoli, Brussels sprouts, cabbage, cauliflower, cucurbits (vine crops), eggplant, peppers, potatoes	BCZ
THIONEX 50 WP	endosulfan	i	50	3	beans (snap), broccoli, Brussels sprouts, cabbage, cauliflower, celery, cucurbits (vine crops), eggplant, lettuce (head), peas, peppers, potatoes, rutabagas, spinach, tomatoes	UAG
thiophanate-methyl	See SENATOR					
THIRAM 75 WP	thiram	s	75	3	beans, beets (table), broccoli, Brussels sprouts, cabbage, cauliflower, cucurbits (vine crops), lettuce, onions, peas, peppers, radishes, rutabagas, spinach, sugarbeets, sweet corn, sweet potatoes	CRE
THURICIDE HPC	<i>Bacillus thuringiensis</i>	i	4,000/mg	4	celery, brassica crops, spinach, tomatoes	VBC
TILT 250 E	propiconazole	f	250 g/L	3	sweet corn	SYZ
TITAN ST	clothianidin	s	600 g/L	2	potatoes	BCZ
TOPAS 250 E	propiconazole	f	250 g/L	3	asparagus, rutabagas	ENG
TUBERSEAL	mancozeb	s	16	4	potato seed piece	NRA
UP-CYDE	cypermethrin	i	250 g/L	3	asparagus, brassica crops, carrots, lettuce, onions, potatoes, rutabagas, sweet corn, tomatoes	UPI
VAPAM	metam sodium	h, f, n	380 g/L	4	preplant site preparation	UAG
VAPAM HL	metam sodium	h, f, n	42	4	preplant site preparation	UAG
vinclozolin	See RONILAN					
VITAFLO 280	carbathiin + thiram	s	15.59 + 13.95	4	beans, peas	BCZ
VYDATE L	oxamyl	i	240 g/L	2	potatoes	DUQ
ZINEB 80 W	zineb	f	80	4	asparagus, carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, lettuce, onions	UAG
zoxamide/mancozeb	See GAVEL					

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Class 4: Restricted - commercial use only; low hazard and/or low persistence

Table 11-2. Pest Control Product Companies

Code	Company/Agent	Website	Contact Number
****	Various manufacturers		
AFG	AEF Global Inc.	www.aefglobal.com	1-888-622-3222
AMV	AMVAC	www.amvac-chemical.com	949-260-1212
AVV	Arvesta Corp.	www.arvesta.com	1-800-642-7635
BAT	Bartlett, N.M. Inc.	www.bartlett.ca	1-800-263-1287
BAZ	BASF Canada Inc.	www.agsolutions.ca	1-877-371-2273
BCZ	Bayer Crop Science	www.bayercropscience.ca	1-888-283-6847
BIB	BioSafe Systems	www.biosafesystems.com	1-888-273-3088
BUL	Buckman Labs of Canada	www.buckman.com	405-424-4404
BWI	BioWorks Inc.	www.bioworksinc.com	585-641-0581
CAU	Cheminova Canada Inc.	www.cheminova.com	519-427-0600
CRE	Chemtura Company	www.chemtura.com	1-866-744-3060
DUQ	Dupont Canada Inc.	www.dupont.ca/ag	1-800-667-3925
DWE	Dow Agrosciences Canada Inc.	www.dowagro.ca	1-800-667-3852
ENG	Engage Agro Corp.	www.engageagro.com	866-613-3336
GOW	Gowan Company	www.gowanco.com	1-800-883-1844
HND	Hendrix and Dail	www.hendrixanddail.com	831-637-0195
ISK	ISK BioSciences	www.iskbc.com	440-357-4640
NRA	Norac Concepts Inc.	www.noracconcepts.com	519-821-3633
NUA	NuFarm Agriculture Inc.	www.nufarm.ca	1-800-868-5444
OMD	Omex Agriculture Inc.	www.omex.com	204-477-4052
PLG	Plant Products Co. Ltd.	www.plantprod.com	1-800-387-2449
SYZ	Syngenta Crop Protection	www.syngenta.ca/	1-877-214-5405
UAG	United Agri Products	www.uap.ca	1-800-265-4624
UPI	United Phosphorus Inc.	www.uplonline.com	
VBC	Valent BioSciences Canada	www.valentbiosciences.com	1-800-682-5368
SFR	Woodstream Canada Corporation		416-291-8150

Table 11-3. Re-Entry Intervals for Pesticides Used on Vegetable Crops

Trade Name(s)	Active Ingredient	Re-Entry Interval	Recommended Crops
Actara	thiamethoxam	12 hr	potatoes
Admire 240F	imidacloprid	24 hr	brassica crops, cucurbits (vine crops) eggplant, lettuce, potatoes, sweet potatoes, tomatoes
Alias 240 EC	imidacloprid	24 hr	lettuce (field), potatoes, sweet potatoes, tomatoes
Aliette WDG	fosetyl-al	12 hr	lettuce, onions, broccoli, bok choy, rutabagas
Allegro 500 F	fluzinam	24 hr	beans, brassica crops, potato
Assail 70 WP	acetamiprid	12 hr	brassica crops, celery, lettuce, endive, parsley, spinach, Swiss chard, leafy greens (see label), peppers, potatoes, rhubarb, tomatoes
Bravo 500	chlorothalonil	48 hr	asparagus, broccoli, Brussels sprouts, cabbage, cauliflower, carrots, celery, cucurbits (vine crops), onions, parsnips, potatoes, sweet corn, tomatoes
Cabrio EG	pyraclostrobin	12 hr (3 days for hand-thinning, pruning and harvest activities)	beets (table), carrots, cucurbits (vine crops), eggplant, garlic, horseradish, onions, peppers, radish, rutabaga, tomatoes
Citation 75 WP	cyromazine	12 hr	brassica leafy greens (see label), celery, lettuce, leafy greens (see label), parsley, spinach, Swiss chard
Coragen 200 SC	chlorantraniliprole	12 hr	brassica crops, leafy greens (see label), potatoes, tomatoes
Counter 15 G	terbufos	48 hr	sugarbeets
Curzate 60 DF	cymoxanil	24 hr	potatoes
Decree 50 WDG	fenhexamid	4 hr	tomato transplants (greenhouse)
Delegate WG	spinetoram	12 hr	asparagus, brassica crops, carrots, leafy vegetables, radish, rutabagas, tomatoes
Dibrom	naled	48 hr	beans (lima), broccoli, Brussels sprouts, cabbage, cauliflower, kale, mustard greens, celery, lettuce, endive, onions, peas, potatoes, spinach, sugarbeets, tomatoes
Entrust 80W	spinosad	potatoes: 12 hr brassica crops*: 72 hr (*hand harvest or tying activities)	beans, brassica crops, eggplant, lettuce, endive, leafy greens, peppers, potatoes, radishes, rhubarb, rutabagas, turnips, spinach, Swiss chard, sweet corn, tomatoes
Fulfill 50WG	pymetrozine	12 hr	potatoes
Gavel 75 DF	zoxamide + mancozeb	48 hr	potatoes
Grapple	imidicloprid	24 hr	brassica crops, cucurbits (vine crops), eggplant, lettuce, potatoes, sweet potatoes, tomatoes
Headline EC	pyraclostrobin	48 hr	beans, peas, potatoes, sugarbeets, sweet corn
Imidan 50 WP	phosmet	5 days	carrots, celery
Kocide 2000	copper hydroxide	greenhouse transplants: 24 hr	peppers, potatoes, tomatoes
Lance WDG	boscalid	4 hr	beans (snap and lima), carrots, cucurbits (vine crops), eggplant, lettuce, onions, peas, peppers, potatoes, tomatoes
Lannate TNG	methomyl	24 hr	beans, broccoli, Brussels sprouts, cabbage, cauliflower, head lettuce, peas, sweet corn, tomatoes
Lorsban	chlorpyrifos	24 hr cauliflower: 10 days	broccoli, Brussels sprouts, cabbage, cauliflower, Chinese cabbage, pak choy, carrots, celery, cucumber, garlic, onions (bulb), radishes, peppers, potatoes, rutabagas, sugarbeets, sweet corn
Maestro 80DF	captan	48 hr	cucumber, tomatoes, vegetable transplants in greenhouse (crucifer, eggplant, pepper, tomatoes, celery)
Manzate Pro-stick	mancozeb	24 hr	carrots, celery, cucurbits (vine crops), onions (dry), potatoes, sugarbeets, tomatoes
Matador 120 EC	lambda-cyhalothrin	24 hr	asparagus, beans, broccoli, Brussels sprouts, cabbage, cauliflower, garlic, lettuce (head), onions, peas, potatoes, sweet corn, sweet potatoes, tomatoes
Microscopic Sulphur	sulphur	24 hr	rutabagas
Monitor 480	methamidophos	48 hr	broccoli, Brussels sprouts, cabbage, cauliflower, lettuce (head), potatoes
Movento 240 SC	spirotetramat	12 hr	brassica crops, celery, cucurbits (vine crops), eggplant, lettuce, peppers, rhubarb, spinach, sweet potatoes, tomatoes
Oberon	spiromesifen	12 hr (2 days for hand thinning activities)	brassica crops, cucurbits (vine crops), eggplant, leafy vegetables, sweet potatoes, tomatoes

Table 11–3. Re-Entry Intervals for Pesticides Used on Vegetable Crops

Trade Name(s)	Active Ingredient	Re-Entry Interval	Recommended Crops
Orthene 75 SP	acephate	12-hr	Brussels sprouts, cabbage, cauliflower, tomatoes
		24-hr	celery, head lettuce ¹ , peppers, potatoes
		5 days	corn
Penncozeb	mancozeb	24 hr	carrots, celery, cucurbits (vine crops), onions (dry), potatoes, sugarbeets
Perm-UP	permethrin	12 hr	asparagus, beans, beets, carrots, brassica crops, lettuce, onions, peas, peppers, potatoes, sugarbeets, sweet corn, tomatoes
Prestop	<i>Glucoladium catenulatum</i>	4 hr	greenhouse herb transplants (oregano, basil, parsley, thyme, dill)
Pristine WG	pyraclostrobin + boscalid	3 days (hand-thinning activities)	carrots, celery, chives, garlic, onions, leeks, shallots, spinach
Pyrifos 15G	chlorpyrifos	24 hr cauliflower: 10 days	broccoli, Brussels sprouts, cabbage, cauliflower, onions
Pyrinex 480 EC	chlorpyrifos	24 hr cauliflower: 10 days	carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, Chinese broccoli, Asian radish, cucumbers, garlic, dry onions, peppers, potatoes, radish, rutabaga, sweet corn
Ranman 400 SC	cyazofamid	12 hr	potatoes, cucurbits (vine crops), carrots
Revus	mandipropamid	12 hr	brassica crops, garlic, lettuce, leeks, onions, pepper (transplants), potatoes, spinach, tomatoes
Ronilan EG	vinclozolin	lettuce: 12 hr	beans, lettuce
Rovral	iprodione	12 hr	beans, cabbages, cauliflower, garlic, leeks, lettuce, dry onions
Silencer	lambda-cyhalothrin	24 hr	asparagus, beans, broccoli, Brussels sprouts, cabbage, cauliflower, garlic, lettuce, onions, peas, potatoes, sweet corn, sweet potatoes, tomatoes
Success 480 SC	spinosad	potatoes: 12 hr brassica crops*: 72 hr (*hand harvest or tying activities)	beans (snap), brassica crops, celery, lettuce, leafy greens, peppers, potatoes, radishes, rhubarb, rutabagas, spinach, Swiss chard, sweet corn, tomatoes
Supra Captan 80 WDG	captan	48 hr	cucumbers, tomatoes, vegetable transplants in greenhouse (brassica crops, eggplant, peppers, tomatoes, celery)
Switch 62.5	cyprodinil/fludioxinil	12 hr	beans, cabbage, carrots, mustard/turnip greens, onions
Tanos 50 DF	famoxadone + cymoxanil	24 hr	potatoes, tomatoes
Tattoo C	propamocarb + chlorothalonil	28 hr (4 hr for short-term tasks)	potatoes, cucurbits (vine crops)
Telone C-17	1,3 dichloropropene + chloropicrin	72 hr	non-crop areas
Telone II	1,3 dichloropropene	72 hr	non-crop areas
UP-cyde	cypermethrin	12 hr	asparagus, brassica crops, carrots, lettuce, onions, potatoes, rutabagas, sweet corn, tomatoes
Vydate L	oxamyl	24 hr	potatoes

¹ Workers must wear gloves in the field for 2-weeks following applications.**Table 11–4. Pesticides Used in Vegetable Crops That Affect Cholinesterase Levels in Blood**

Product Name	Common Name(s)
acephate	Orthene 75 SP
carbaryl	Sevin XLR
chlorpyrifos	Lorsban 50 W, Pyrifos 15 G, Pyrifos 50 W, Pyrinex 480 EC
diazinon	Diazinon 50 W, Diazinon 500 E, Agrox B-2, Agrox CD
dimethoate	Cygon 480, Lagon 480 E
malathion	Malathion 25 W, Malathion 500 E
methamidophos	Monitor 480
methomyl	Lannate
naled	Dibrom
oxamyl	Vydate L
phosmet	Imidan 50 W
terbufos	Counter

12. Appendices

Appendix A. Ontario Ministry of Agriculture, Food and Rural Affairs Vegetable Crop Advisory Staff

A complete list of OMAFRA advisory staff is available on the OMAFRA website at www.ontario.ca/crops.

Specialty	Staff	Tel/Fax	E-mail
Brighton Resource Centre			
95 Dundas St. E, RR#3, Brighton, ON K0K 1H0			
IPM Systems Specialist	Margaret Appleby	Tel: 613-475-5850 Fax: 613-475-3835	margaret.appleby@ontario.ca
Guelph OMAFRA			
1 Stone Rd. W., Guelph, ON N1G 4Y2			
Crop Protection Program Lead	Denise Beaton	Tel: 519-826-6594 Fax: 519-826-4964	denise.beaton@ontario.ca
Minor Use Coordinator	Jim Chaput	Tel: 519-826-3539 Fax: 519-826-4964	jim.chaput@ontario.ca
Organic Crop Production Program Lead	Hugh Martin	Tel: 519-826-4587 Fax: 519-826-4964	hugh.martin@ontario.ca
Potato Specialist	Eugenia Banks	Tel: 519-826-3678 Fax: 519-826-4964	eugenia.banks@ontario.ca
Vegetable Crops Specialist	vacant	Tel: 519-826-4963 Fax: 519-826-4964	
Ridgetown Resource Centre			
Agronomy Building, Ridgetown College, Box 400, Main St. E., Ridgetown, ON N0P 2C0			
Soil Management Specialist – Hort Crops	Anne Verhallen	Tel: 519-674-1614	anne.verhallen@ontario.ca
Vegetable Crops Specialist	Janice LeBoeuf	Tel: 519-674-1699	janice.leboeuf@ontario.ca
Vegetable Crops Specialist	Elaine Roddy	Tel: 519-674-1616	elaine.rodody@ontario.ca
Weed Management Program Lead – Horticulture	Kristen Callow	Tel: 519-674-1335	kristen.callow@ontario.ca
Simcoe Resource Centre			
P.O. Box 587, Blueline Rd. & Hwy #3, Simcoe, ON N3Y 4N5			
Application Technology Specialist	Jason Deveau	Tel: 519-426-8934	jason.deveau@ontario.ca
Fresh Market Quality Program Lead	Jennifer R. DeEll	Tel: 519-426-1408	jennifer.deell@ontario.ca
Vineland Resource Centre			
Adv. Serv. Building, Box 8000, 4890 Victoria Ave. N., Vineland Station, ON L0R 2E0			
Entomologist – Horticulture Program Lead	Hannah Fraser	Tel: 905-562-1674	hannah.fraser@ontario.ca
Nutrient Management Horticulture Crops Program Lead	Donna Speranzini	Tel: 905-562-1170	donna.speranzini@ontario.ca
University of Guelph			
50 Stone Rd. E., Guelph, ON N1G 2W1			
Nutrition – Horticulture Program Lead Land Resource Science, Richards Building	Christoph Kessel	Tel: 519-824-4120, ext. 52480 Fax: 519-824-5730	christoph.kessel@ontario.ca
Pathologist – Horticulture Program Lead Edmund Bovey Building	Michael Celetti	Tel: 519-824-4120, ext. 58910 Fax: 519-767-0755	michael.celetti@ontario.ca

Agricultural Information Contact Centre

Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.

1 Stone Rd. W.
Guelph, ON N1G 4Y2

Tel: 1-877-424-1300

Fax: 519-826-3442

E-mail: ag.info.omafra@ontario.ca

Appendix B. Ontario Ministry of Environment — Regional Contact Information

Region/County	Address	Telephone/fax
Central Region Toronto, Halton, Peel, York, Durham, Muskoka, Simcoe	5775 Yonge St., 8th Floor Toronto, ON M2M 4J1	Tel: 416-326-6700 Toll-free: 1-800-810-8048 Fax: 416-325-6345
West-Central Region Haldimand, Norfolk, Niagara, Hamilton-Wentworth, Dufferin, Wellington, Waterloo, Brant	Ontario Government Building 119 King St. W., 12th Floor Hamilton, ON L8P 4Y7	Tel: 905-521-7640 Toll-free: 1-800-668-4557 Fax: 905-521-7820
Eastern Region Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/Dundas & Glengarry, Haliburton, Peterborough, Kawartha Lakes, Northumberland, Renfrew, Ottawa, Lanark, District of Nipissing (Twp. of South Algonquin)	1259 Gardiners Rd., Unit 3 PO Box 22032 Kingston, ON K7M 8S5	Tel: 613-549-4000 Toll-free: 1-800-267-0974 Fax: 613-548-6908
Southwestern Region Elgin, Middlesex, Oxford, Essex, Kent, Lambton, Bruce, Grey, Huron, Perth	733 Exeter Rd. London, ON N6E 1L3	Tel: 519-873-5000 Toll-free: 1-800-265-7672 Fax: 519-873-5020
Northern Region (East) Manitoulin, Nipissing, Parry Sound, Sudbury, Algoma (East), Timiskaming, Sault Ste. Marie	199 Larch St., Ste. 1201 Sudbury, ON P3E 5P9	Tel: 705-564-3237 Toll-free: 1-800-890-8516 Fax: 705-564-4180
Northern Region (West) Algoma (West), Cochrane, Kenora, Rainy River, Timmins, Thunder Bay	435 James St. S., Ste. 331 Thunder Bay, ON P7E 6S7	Tel: 807-475-1205 Toll-free: 1-800-875-7772 Fax: 807-475-1745
Standards Development Branch	Pesticides Section 40 St. Clair Ave. W. 7th Floor Toronto, ON M4V 1L5	Tel: 416-327-5519 Fax: 416-327-2936
Approvals Branch	Pesticides Licensing 2 St. Clair Ave. W. 12A Floor Toronto, ON M4V 1L5	Tel: 416-314-8001 Toll-free: 1-800-461-6290 Fax: 416-314-8452

Appendix C. Accredited Soil-Testing Laboratories in Ontario

The following labs are accredited to perform soil tests for pH, buffer pH, P, K, Mg and Nitrate-N on Ontario soils.

Laboratory Name	Address	Telephone/Fax/E-mail	Contact
A & L Canada Laboratories Inc. Website: www.alcanada.com	2136 Jetstream Rd. London, ON N5V 3P5	Tel: 519-457-2575 Fax: 519-457-2664 E-mail: aginfo@alcanada.com	Greg Patterson Ian McLachlin
Agri-Food Laboratories Website: www.agtest.com	503 Imperial Rd. Unit #1 Guelph, ON N1H 6T9	Tel: 519-837-1600 1-800-265-7175 Fax: 519-837-1242 E-mail: lab@agtest.com	Trish Kelly Jack Legg
Brookside Laboratories, Inc. Website: www.blinc.com/	308 South Main St. New Knoxville, Ohio US 45871	Tel: 419-753-2448 Fax: 419-753-2949 E-mail: jbrackman@blinc.com	Jackie Brackman Mark Flock
Exova Accutest Laboratory Exova Canada Inc. Website: www.exova.ca	8-146 Colonnade Rd. Ottawa, ON K2E 7Y1	Tel: 613-727-5692, ext. 317 Fax: 613-727-5222 E-mail: lorna.wilson@bodycote.com	Lorna Wilson
FoReST Laboratory Website: http://lucas.lakeheadu.ca/forest/	955 Oliver Rd. BB1005D Thunder Bay, ON P7B 5E1	Tel: 807-343-8639 Fax: 807-343-8116 E-mail: soilslab@lakeheadu.ca	Claire Riddell Joel Symonds
University of Guelph Laboratory Services Website: www.labservices.uoguelph.ca/units/soil-nutrient/	University of Guelph P.O. Box 3650, 95 Stone Rd. W. Guelph, ON N1H 8J7	Tel: 519-767-6299 Fax: 519-767-6240 E-mail: aflinfo@uoguelph.ca	Nick Schrier
Stratford Agri Analysis Website: www.stratfordagri.ca/	1131 Erie St. Box 760 Stratford, ON N5A 6W1	Tel: 519-273-4411 1-800-323-9089 Fax: 519-273-2163 E-mail: info@stratfordagri.ca	Keith Lemp Mark Aikman

There is no official accreditation in Ontario for tissue analysis, but all the accredited soil-testing labs are monitored for proficiency on tissue analyses.

Appendix D. Vegetable Seed Suppliers**Wholesale Seed Companies (Sales to Dealers)**

*Most sites include list of dealers

American Takii Inc.

www.takii.com
 301 Natividad Rd., Salinas, CA 93906 US
 Tel: 831-443-4901 Fax: 831-443-3976

Crookham Co. Inc.

www.crookham.com
 Box 520, Caldwell, ID 83606-0520 US
 Tel: 208-459-7451 Fax: 208-454-2108
 E-mail: ccoinfo@crookham.com

Hollar Seeds

(Cucurbit Seeds)
 www.hollarseeds.com
 Box 106, Rockyford, CO 81067 US
 Tel: 719-254-7411 Fax: 719-254-3539

Nunhems

www.nunhems.com/index.html
 1200 Anderson Corner Rd., Parma, ID 83660 US
 Tel: 1-800-733-9505
 E-mail: customer.service.usa@nunhems.com

Seminis (Asgrow, Peto Seeds, Royal Sluis, Hungnong)

www.seminis.com
 Ron Garton
 613 Tomahawk Cres., Ancaster, ON L9G 3T4
 Tel: 905-304-1795 Fax: 905-304-3820
 E-mail: ron.garton@seminis.com

Syngenta Seeds – ROGERS® Brand

www.rogersadvantage.com
 Bob Kotch
 573 Gardener Rd., Horseheads, NY 14845-1237 US
 Tel: 607-739-0191
 E-mail: bob.kotch@syngenta.com

Retail Seed Companies (Sales to Growers)

*Sales through sales reps, catalogue, website

Abbot & Cobb

www.acseed.com
 Tel: 1-800-345-7333

AgroHaitai Ltd.

www.AgroHaitai.com
 2764 Governor's Road (Hwy 99), P.O. Box 45, Lynden ON L0R 1T0
 Tel: 519-647-2280 Fax: 519-647-3188
 E-mail: seed@agrohaitai.com

August's Harvest Inc.

Warren Ham
 www.augustsharvest.com
 4727 Rd 130, RR#2, Gadshill ON N0K 1J0
 Tel: 519-393-5550 Fax: 519-393-5556
 Cell: 274-9841
 Toll-free 877-272-1742
 E-mail: warren@augustsharvest.com

Boundary Garlic

www.garlicfarm.ca
 Box 273, Midway, BC V0H 1M0
 Tel: 250-449-2152
 E-mail: sonia@garlicfarm.ca

Dominion Seed House

www.dominion-seed-house.com
 Box 2500, Georgetown, ON L7G 5L6
 Tel: 905-873-3037 Fax: 1-800-282-5746
 E-mail: mail@dominion-seed-house.com

Evergreen Seeds

(Oriental Vegetable Seeds)
 www.store.yahoo.com/evergreenseeds/index.html
 Box 17538, Anaheim, CA 92817 USA
 Tel/Fax: 714-637-5769

Fred Fuller Seeds Ltd.

(Sales Agent for Co-Op Uniforce, Quebec)
 Fred Fuller
 19075 Dufferin St., Newmarket, ON L3Y 4V9
 Tel: 905-775-9696 Fax: 905-551-0910
 E-mail: fuller.seeds@rogers.com

Harris-Moran

www.harrismoran.com
 John Molyet, Fresh Market, Senior Sales Representative
 Eastern Canada, Northeastern, Midwestern USA
 Cell: 419-902-0414
 E-mail: j.molyet@hmclosure.com

Heirloom Acres Seeds

www.heirloomacresseeds.com
 Box 194, New Bloomfield, MO, 65063 USA
 Tel: 573-491-3001
 E-mail: kirk@heirloomacresseeds.com

Johnny's Selected Seeds

www.johnnyseeds.com
 955 Benton Ave., Winslow, Maine 04901-2601 USA
 Tel: 207-861-3900 or 1-877-564-6697
 Fax: 207-861-8377
 E-mail: service@johnnyseeds.com

Norseco Seeds

Robert Dumolin
 2914 Cure-Labelle Blvd., Laval, QC H7P 5R9
 Tel: 1-800-561-9693 Fax: 1-800-567-4594
 E-mail: order@norseco.com

Ontario Seed (OSC)

www.oscseeds.com
 Box 7, Waterloo, ON N2J 3Z6
 Tel: 519-886-0557 Fax: 519-886-0605
 E-mail: seeds@oscseeds.com

Ornamental Edibles

www.ornamentaledibles.com
 5723 Trowbridge Way, San Jose, CA 95138 USA
 Tel: 408-528-7333 Fax: 408-532-1499
 E-mail: seeds@ornamentaledibles.com

Redwood City Seed Co.

www.ecoseeds.com
 Craig & Sue Dremann
 Box 361, Redwood City, CA 94064 USA
 Tel: 650-325-7333 Fax: 650-325-4056

Reed's Seeds

3334 N.Y.S. Rt. 215, Courtland, NY 13045-9433 USA
 Tel: 607-753-9095 Fax: 607-753-9511

Rijk Zwaan (Greenhouse Vegetable Seeds)

www.rijkszwaan.com

Richter's (Herbs)

www.richters.com
 357 Highway 47, Goodwood, ON L0C 1A0
 Tel: 905-640-6677 Fax: 905-640-6641
 E-mail: orderdesk@richters.com

Rispens Seeds Inc.

www.rispensseeds.com
 1357 Dutch American Way, P.O. Box 310
 Beecher, IL 60401 US
 Tel: 708-946-6560 (Canada) or 1-888-874-0241 (U.S. only)
 Fax: 708-946-6115

Rupp Seeds

www.ruppseeds.com
 George Wonnacott
 135 Lancefield Place, Chatham, ON N7L 2M5
 Tel: 519-354-0206 Fax: 519-354-0287
 E-mail: georgew@ruppseeds.com

Sakata Seed Inc.

www.sakata.com
 Dennis Thome
 1365 S. Bates St., Birmingham, Michigan 48009 US
 Tel: 248-709-5684
 E-mail: dthome@sakata.com

Seedway/Bejo

(Distributors of Bejo Varieties)
 www.seedway.com
 99 Industrial Rd., Elizabethtown, PA 17022 USA
 Tel: 1-800-952-7333 Fax: 1-800-645-2574
 E-mail: vegseed@seedway.com

Siegers Seed Company

www.siegers.com
 Ernie Szucs
 Cell: 814-460-4102
 Tel: 519-586-2110 Fax: 519-586-2555
 E-mail: ernie_szucs@siegers.com

Stokes Seeds

www.stokesseeds.com
 Paul Banks
 Box 10, Thorold, ON L2V 5E9
 Tel: 1-800-263-7233

Jim Robinson

Box 144, Rockton, ON L0R 1X0
 Tel: 905-715-8595

Syngenta Seeds

77 Southridge, Springgrove, PA 17362 US
 Bill Rankin, Processing
 Tel: 717-225-5557 Fax: 717-739-1032
 E-mail: b.rankin@syngenta.com

Terralink Horticulture Inc.

www.tlhort.com
 464 Riverside Rd., Abbotsford, BC V2S 7M1
 Tel: 1-800-661-4559 or 604-864-9044 Fax: 604-864-8418

Tomato Growers' Supply Company

www.tomatogrowers.com
 P.O. 60015, Fort Myers, FL, 33906 USA
 Tel: 1-239-768-1119

Tomato Solutions

www.tomatosolutions.ca
 Jim Dick and Adam Dick
 R. R. # 4, 23264 Mull Rd., Chatham, ON N7M 5J4
 Tel: 519-354-3039 Fax: 519-354-2058
 E-mail: jimdick@netrover.com

Totally Tomatoes

www.totallytomato.com
 334 West Stroud St., Randolph, WI 53956 US
 Tel: 1-800-345-5977 Fax: 1-888-477-7333
 E-mail: info@totallytomato.com

Vesey's Seeds

www.veseys.com
 Box 9000, Charlottetown, PE, C1A 8K6
 Tel: 1-800-363-7333 Fax: 1-800-686-0329
 E-mail: customerservice@veseys.com

West Coast Seeds Ltd.

www.westcoastseeds.com
 3925 64th St., RR 1, Delta BC V4K 3N2
 Tel: 604-952-8820 Fax: 604-952-882
 Toll-free: 1-888-804-8820
 Email: info@westcoastseeds.com

William Dam Seeds

www.damseeds.com
 279, Highway # 8, RR # 1
 Dundas, ON L9H 5E1
 Tel: 905-628-6641 Fax: 905-627-1729
 E-mail: info@damseeds.com

Appendix E. Production Insurance

Production insurance (PI) is a production-based insurance program that protects farmers against yield reductions and crop losses due to adverse weather and other insured perils such as excessive rain, hail, drought and plant diseases. In Ontario, Agricorp administers PI on behalf of the Government of Ontario and Agriculture and Agri-Food Canada. More than 16,000 producers and 2 million hectares (5 million acres) of Ontario farmland are insured each year.

The federal and provincial governments pay up to 60% of the required PI premiums and 100% of the administration cost of delivering PI. Premium payments from all producers are pooled together into one fund, which is then used to pay claims. In this manner, the claims of a small number of producers are spread over all producers in the program. Claim payments are limited to the producer's guaranteed yield at the insured price.

PI is available to all Ontario farmers, landlords and sharecroppers who grow an eligible crop. Coverage is available on 90 commercially grown crops in Ontario in the following sectors:

- forage
- tree fruit and grapes
- strawberries
- honey
- grains and oilseeds
- vegetables
- seed corn, sugar beets, hemp and tobacco

For more information, please call Agricorp weekdays, 7 AM to 5 PM at 1-888-247-4999 or visit www.agricorp.com.

Agricorp
1 Stone Rd. W., Box 3660, Stn. Central
Guelph, ON N1H 8M4
Tel: 1-888-247-4999
Fax: 519-826-4118
E-mail: contact@agricorp.com
www.agricorp.com

Ontario Crops Covered by Production Insurance

Fruit Crops

apples and apple trees	cherries, sweet and sour	grapes and grape vines
peaches/nectarines	pears	plums
strawberries		

Vegetable Crops – Average Farm Yield or Total Production

asparagus	banana peppers	bell peppers
broccoli	green beans and wax beans (processing)	butternut squash (processing)
cabbages	carrots (fresh)	carrots (processing)
cauliflower	celery	cucumbers (processing)
lettuce	lima beans (processing)	parsnips
peas (processing)	potatoes (fresh)	potatoes (processing)
red beets (processing)	rutabagas	seed onions
set onions	spanish onions	sweet corn (fresh)
sweet corn (processing)	tomatoes (fresh)	tomatoes (processing)

Fresh Market Vegetables – Acreage Loss

Root Vegetables (red beets, carrots, celeriac, French shallots, green onions, leeks, onions, parsnips, radishes, rutabagas, turnips, sweet potatoes, garlic)

Leafy Vegetables (Brussels sprouts, broccoli, cauliflower, broccoflower, celery, Chinese cabbages, summer & winter cabbage, lettuce, mesclun, spinach, kale)

Fruit Vegetables (cucumbers, eggplant, gherkins, melons, peppers, pumpkins, squash, tomatoes, zucchinis)

Other Vegetables (broad beans, green and wax beans, sweet corn, green peas)

General Crops

canola	coloured beans (black, cranberry, kidney, Japanese/other)	corn (grain and silage)
forage	hemp, industrial	honey
mustard	new forage seeding	peanuts
popping corn	soybeans (tofu, natto and organic options available)	spring grain
seed corn	spring wheat	sugarbeets
sunflower	white beans	winter spelt, organic
winter wheat, hard red	winter wheat, organic	winter wheat, soft red
winter wheat, soft white		

Tobacco

black	burley	flue-cured
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Appendix F. Other Contacts

AGRICULTURE & AGRI-FOOD CANADA RESEARCH CENTRES

http://www.agr.gc.ca/index_e.php

Eastern Cereals and Oilseeds Research Centre

960 Carling Ave.
Ottawa, K1A 0C6
Tel: 613-759-1858

Greenhouse and Processing Crops Centre

2585 County Road 20
Harrow, N0R 1G0
Tel: 519-738-2251

Southern Crop Protection and Food Research Centre

1391 Sandford St.
London, N5V 4T3
Tel: 519-457-1470

Vineland Research Farm
4902 Victoria Ave. N.
Vineland, L0R 2E0
Tel: 905-562-4113

Delhi Research Farm
Box 186 Schafer Rd.
Delhi, N4B 2W9
Tel: 519-582-1950

CANADIAN FOOD INSPECTION AGENCY REGIONAL OFFICES (PLANT PROTECTION)

www.inspection.gc.ca/english/toce.shtml

Belleville

345 College St. E.
Belleville, K8N 5S7
Tel: 613-969-3333

Brantford

625 Park Rd. N., Ste. 6
Brantford, N3T 5P9
Tel: 519-753-3478

Hamilton

709 Main St. W., Ste. 101
Hamilton, L8S 1A2
Tel: 905-572-2201

London

19-100 Commissioners Rd. E.
London, N5Z 4R3
Tel: 519-691-1300

St. Catharines

395 Ontario St., Box 19
St. Catharines, L2N 7N6
Tel: 905-937-8232

Ottawa District

38 Auriga Dr., Unit 8
Ottawa K2E 8A5
Tel: 613-274-7374, ext. 221

Toronto

1124 Finch Ave. W., Unit 2
Downsview, M3J 2E2
Tel: 416-665-5055

UNIVERSITY OF GUELPH

Main Campus

Guelph, N1G 2W1
Tel: 519-824-4120
www.uoguelph.ca

Alfred Campus

Alfred, K0B 1A0
Tel: 613-679-2218
Fax: 613-679-2423
www.alfredc.uoguelph.ca

Kemptville Campus

Kemptville, K0G 1J0
Tel: 613-258-8336
Fax: 613-258-8384
www.kemptvillec.uoguelph.ca

Ridgetown Campus

Ridgetown, N0P 2C0
Tel: 519-674-1500
www.ridgetownc.on.ca

Department of Plant Agriculture

www.plant.uoguelph.ca

Department of Plant Agriculture, Guelph

50 Stone Rd. W.
Guelph, N1G 2W1
Tel: 519-824-4120, ext. 56083
Fax: 519-763-8933

Department of Plant Agriculture, Simcoe

1283 Blueline Rd., Box 587
Simcoe, N3Y 4N5
Tel: 519-426-7127
Fax: 519-426-1225

Department of Plant Agriculture, Vineland

Box 7000, 4890 Victoria Ave. N.
Vineland Station, L0R 2E0
Tel: 905-562-4141
Fax: 905-562-3413

Lab Services Division

www.uoguelph.ca/labserv/
P.O. Box 3650, 95 Stone Rd. W.
Guelph, N1H 8J7
Tel: 519-767-6299

Trace Organics and Pesticides

Tel: 519-767-6485

Pest Diagnostic Clinic

Tel: 519-767-6256

Appendix G. Diagnostic Services

Samples for disease diagnosis, insect or weed identification, nematode counts and Verticillium testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Rd. W.
Guelph Ontario, N1H 8J7

Tel: 519-767-6256
Fax: 519-767-6240
E-mail: pdc@lsd.uoguelph.ca

Payment must accompany samples at the time of submission. Submission forms are available at www.uoguelph.ca/pdc.

Fee Schedule

To obtain information on the fee schedule, visit www.uoguelph.ca/pdc or phone the Pest Diagnostic Clinic.

How to Sample for Nematodes

Soil

When to Sample

Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June and again in September and October.

How to Sample Soil

Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm. If the soil is bare, remove the top 2 cm prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of ½–1 L from this. No one sample should represent more than 2.5 ha. Mix subsamples in a clean pail or plastic bag.

Sampling Pattern

If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of Subsamples

Based on the total area sampled:

500 m ²	10 subsamples
500 m ² –0.5 ha	25 subsamples
0.5 ha–2.5 ha	50 subsamples

Roots

From small plants, sample the entire root system plus adhering soil. For large plants, 10–20 g, dig fresh weight from the feeder root zone and submit.

Problem Areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, take both soil and root samples from problem and healthy areas in the same field.

Sample Handling

Soil Samples

Place in plastic bags as soon as possible after collecting.

Root Samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Store samples at 5°C–10°C and do not expose them to direct sunlight or extreme heat or cold (freezing). Only living nematodes can be counted. Accurate counts depend on proper handling of samples.

Submitting Plant for Disease Diagnosis or Identification

Sample Submission Forms

Forms can be obtained from your local Ontario Ministry of Agriculture, Food and Rural Affairs office. Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past 3 years and this year's pesticide use records.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system, or several plants showing a range of symptoms. If symptoms are general, collect the sample from an area where they are of intermediate severity. Completely dead material is usually inadequate for diagnosis.

With plant specimens submitted for identification, include at least a 20–25-cm sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid drying out and contamination of the leaves by soil. Do NOT add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or by courier at the beginning of the week.

Submitting Insect Specimens for Identification

Collecting Samples

Place dead, hard-bodied insects in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this results in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.



95 Stone Road West
Guelph, ON N1H 8J7
Tel: (519) 767-6256
Fax: (519) 767-6240
Web: www.uoguelph.ca/pdc

Pest Diagnostic Clinic

SAMPLE SUBMISSION FORM

LABORATORY USE ONLY: LS Form: SubP01/04/03 Pg. 1 of 1

Rec'd By: _____ Date Received: _____

Delivered By: ☐ Mail ☐ Courier ☐ In-Person

LS Sample No: _____ to _____

Payment Rec'd: \$ _____ Receipt #: _____

Submitted By: _____ Owner (if different from submitter): _____

Business Name (if applicable): _____ Business Name (if applicable): _____

Street: _____ Street: _____

City: _____ Prov: _____ Postal Code: _____ City: _____ Prov: _____ Postal Code: _____

Tel: () - _____ Fax: () - _____ Tel: () - _____ Fax: () - _____

Email: _____ Email: _____

Unless otherwise indicated, report and invoice will be sent to submitter

Report to: ☐ Submitter ☐ Owner Required Report Format: ☐ Fax ☐ E-Mail ☐ Mail

Invoice to: ☐ Submitter ☐ Owner Quotation #: _____ Purchase Order / U of G G/L code: _____

Services Required: ☐ Nematode Count ☐ Nematode Count from Roots ☐ SCN Cyst & Egg Count
☐ Plant Disease Diagnosis ☐ Insect Identification ☐ Plant Identification ☐ Verticillium Count

Plant or Host Affected: _____ Cultivar/Variety: _____ Grower/Field sample #: _____

Location of Plant (i.e. greenhouse, field, orchard, garden, etc.): _____

Size of Planting: _____ % of Plants Affected: _____ Symptoms First Appeared in Past: _____ Degree of Injury: _____
☐ Days ☐ Weeks ☐ Months ☐ Years ☐ Severe ☐ Moderate ☐ Light

Cropping History: _____ Future Crop: _____

Describe the problem in detail (i.e. symptoms, plant parts affected, distribution of symptoms):

Were chemicals applied? Please specify type of product(s) used and date(s) of application:

Additional comments and specific requests:

Additional Sheet(s) Attached: ☐

Appendix H. The Metric System

METRIC UNITS

Linear Measures (length)

10 millimetres (mm)	= 1 centimetre (cm)
100 centimetres (cm)	= 1 metre (m)
1,000 metres (m)	= 1 kilometre (km)

Square Measures (area)

100 m x 100 m = 10,000 m ²	= 1 hectare (ha)
100 hectares	= 1 square kilometre (km ²)

Cubic Measures (volume)

Dry Measure

1,000 cubic millimetres (mm ³)	= 1 cubic centimetre (cm ³)
1,000,000 cubic centimetres (cm ³)	= 1 cubic metre (m ³)

Liquid Measure

1,000 millilitres (mL)	= 1 litre (L)
100 litres (L)	= 1 hectolitre (hL)

Weight-Volume Equivalents (for water)

(1.00 kg) 1,000 grams	= 1 litre (1.00 L)
(0.50 kg) 500 grams	= 500 millilitres (0.50 L)
(0.10 kg) 100 grams	= 100 millilitres (0.10 L)
(0.01 kg) 10 grams	= 10 millilitres (0.01 L)
(0.001 kg) 1 gram	= 1 millilitre (0.001 L)

Weight Measures

1,000 milligrams (mg)	= 1 gram (g)
1,000 grams (g)	= 1 kilogram (kg)
1,000 kilograms (kg)	= 1 tonne (t)
1 milligram/kilogram	= 1 part per million (ppm)

Dry-Liquid Equivalents

1 cubic centimetre (cm ³)	= 1 millilitre (mL)
1 cubic metre (m ³)	= 1,000 litres (L)

APPLICATION RATE CONVERSIONS

Metric to Imperial or US (Approximate)

litres per hectare x 0.09	= gallons per acre
litres per hectare x 0.36	= quarts per acre
litres per hectare x 0.71	= pints per acre
millilitres per hectare x 0.015	= fluid ounces per acre
grams per hectare x 0.015	= ounces per acre
kilograms per hectare x 0.89	= pounds per acre
tonnes per hectare x 0.45	= tons per acre

Imperial or US to Metric (Approximate)

gallons per acre x 11.23	= litres per hectare (L/ha)
quarts per acre x 2.8	= litres per hectare (L/ha)
pints per acre x 1.4	= litres per hectare (L/ha)
fluid ounces per acre x 70	= millilitres per hectare (mL/ha)
tons per acre x 2.24	= tonnes per hectare (t/ha)
pounds per acre x 1.12	= kilograms per hectare (kg/ha)
ounces per acre x 70	= grams per hectare (g/ha)

Metric Conversions

5 mL	= 1 tsp
15 mL	= 1 tbs
28.5 mL	= 1 fl. oz

DRY WEIGHT EQUIVALENTS

Metric	Imperial
100 grams/hectare (g/ha)	= 1 1/2 ounces/acre (oz/acre)
200 grams/hectare (g/ha)	= 3 ounces/acre (oz/acre)
300 grams/hectare (g/ha)	= 4 1/4 ounces/acre (oz/acre)
500 grams/hectare (g/ha)	= 7 ounces/acre (oz/acre)
700 grams/hectare (g/ha)	= 10 ounces/acre (oz/acre)
1.10 kilograms/hectare (kg/ha)	= 1 pound/acre (lb/acre)
1.50 kilograms/hectare (kg/ha)	= 1 1/4 pounds/acre (lb/acre)
2.00 kilograms/hectare (kg/ha)	= 1 1/2 pounds/acre (lb/acre)
2.50 kilograms/hectare (kg/ha)	= 2 1/4 pounds/acre (lb/acre)
3.25 kilograms/hectare (kg/ha)	= 3 pounds/acre (lb/acre)
4.00 kilograms/hectare (kg/ha)	= 3 1/2 pounds/acre (lb/acre)
5.00 kilograms/hectare (kg/ha)	= 4 1/2 pounds/acre (lb/acre)
6.00 kilograms/hectare (kg/ha)	= 5 1/4 pounds/acre (lb/acre)
7.50 kilograms/hectare (kg/ha)	= 6 1/2 pounds/acre (lb/acre)
9.00 kilograms/hectare (kg/ha)	= 8 pounds/acre (lb/acre)
11.00 kilograms/hectare (kg/ha)	= 10 pounds/acre (lb/acre)
13.00 kilograms/hectare (kg/ha)	= 11 1/2 pounds/acre (lb/acre)
15.00 kilograms/hectare (kg/ha)	= 13 1/2 pounds/acre (lb/acre)

LIQUID EQUIVALENTS

Litres/Hectare	Approximate Gallons/Acre
50	= 5
100	= 10
150	= 15
200	= 20
250	= 25
300	= 30

ABBREVIATIONS

%	= per cent (by weight)	km/h	= kilometres per hour
ai	= active ingredient	kPa	= kilopascal
AP	= agricultural powder	L	= litre
cm	= centimetre	m	= metre
cm ²	= square centimetre	m/sec	= metres per second
DG	= dispersible granular	m ²	= square metre
DP	= dispersible powder	mL	= millilitre
E	= emulsifiable	mm	= millimetre
e.g.	= for example	SC	= sprayable concentrate
EC	= emulsifiable concentrate	SP	= soluble powder
F	= flowable	t	= tonne
g	= gram	W	= wettable (powder)
Gr	= granules, granular	WDG	= water dispersible granular
ha	= hectare	WP	= wettable powder
kg	= kilogram	km/h	= kilometres per hour

Appendix H. The Metric System (continued)

CONVERSION TABLES —
METRIC TO IMPERIAL

Length

1 millimetre (mm)	= 0.04 inch (in.)
1 centimetre (cm)	= 0.40 inch (in.)
1 metre (m)	= 39.40 inches (in.)
1 metre (m)	= 3.28 feet (ft)
1 metre (m)	= 1.09 yards (yd)
1 kilometre (km)	= 0.62 mile (mi)

Area

1 square centimetre (cm ²)	= 0.16 square inch (in. ²)
1 square metre (m ²)	= 10.77 square feet (ft ²)
1 square metre (m ²)	= 1.20 square yards (yd ²)
1 square kilometre (km ²)	= 0.39 square mile (mi ²)
1 hectare (ha)	= 107,636 square feet (ft ²)
1 hectare (ha)	= 2.5 acres (acre)

Volume (dry)

1 cubic centimetre (cm ³)	= 0.061 cubic inch (in. ³)
1 cubic metre (m ³)	= 1.31 cubic yards (yd ³)
1 cubic metre (m ³)	= 35.31 cubic feet (ft ³)
1,000 cubic metres (m ³)	= 0.81 acre-foot
1 hectolitre (hL)	= 2.8 bushels (bu)

Volume (liquid)

1 millilitre (mL)	= 0.035 fluid ounce (Imp.)
1 litre (L)	= 1.76 pints (Imp.)
1 litre (L)	= 0.88 quart (Imp.)
1 litre (L)	= 0.22 Imperial gallons (gal)
1 litre (L)	= 0.26 U.S. gallon (U.S. gal)

Weight

1 gram (g)	= 0.035 ounce (oz.)
1 kilogram (kg)	= 2.21 pounds (lb)
1 tonne (t)	= 1.10 short tons
1 tonne (t)	= 2,205 pounds (lb)

Pressure

1 kilopascal (kPa)	= 0.15 pounds/square inch (lb/in. ²)
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Speed

1 metre per second (m/sec)	= 3.28 feet per second (ft/sec)
1 metre per second (m/sec)	= 2.24 miles per hour (mph)
1 kilometre per hour (km/h)	= 0.62 mile per hour (mph)

Temperature

°F	= (°C x $\frac{9}{5}$) + 32
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CONVERSION TABLES —
IMPERIAL TO METRIC

Length

1 inch (in.)	= 2.54 centimetres (cm)
1 foot (ft)	= 0.30 metre (m)
1 yard (yd)	= 0.91 metre (m)
1 mile (mi)	= 1.61 kilometre (km)

Area

1 square foot (ft ²)	= 0.09 square metres (m ²)
1 square yard (yd ²)	= 0.84 metre (m ²)
1 acre (ac)	= 0.40 hectare (ha)

Volume (dry)

1 cubic yard (yd ³)	= 0.76 cubic metre (m ³)
1 bushel (bu)	= 36.37 litres (L)

Volume (liquid)

1 fluid ounce (Imp.)	= 28.41 millilitres (mL)
1 pint (Imp.)	= 0.57 litre (L)
1 gallon (Imp.)	= 4.55 litres (L)
1 gallon (U.S.)	= 3.79 litres (L)

Weight

1 ounce (oz)	= 28.35 grams (g)
1 pound (lb)	= 453.6 grams (g)
1 ton	= 0.91 tonne (t)

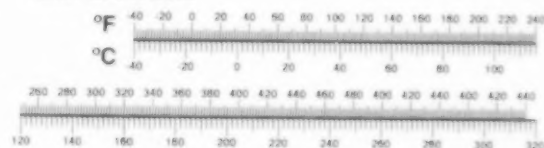
Pressure

1 pound per square inch (lb/in. ²)	= 6.90 kilopascals (kPa)
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Temperature

°C	= (°F - 32) x $\frac{5}{9}$
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TEMPERATURE



For exact values the formula is:

Fahrenheit to Celsius: subtract 32 from number of °F, then multiply by $\frac{5}{9}$

Celsius to Fahrenheit multiply °C by $\frac{9}{5}$ then add 32.



Emergency and First-Aid Procedures for Pesticide Poisoning

For a major spill, a theft or a fire involving a pesticide call the Ministry of the Environment at
1-800-268-6060.

For pesticide poisonings and pesticide injuries call the Poison Information Centre:
Toronto 1-800-268-9017
1-877-750-2233 (TTY)

PREVENT ACCIDENTS

- **Read the label.** Follow all the precautions the label recommends. Read the First Aid section of the label **BEFORE** you begin to handle any pesticide.
- **Make sure that someone knows** what pesticides you are working with and where you are.
- **Keep a file of labels and product Material Safety Data Sheets (MSDS) for the pesticides you use.** Make sure everyone knows where to find this in case of an emergency.
- **Post emergency numbers near all telephones.**
- **Keep clean water, paper towels, extra gloves and clean coveralls close by** in case you spill pesticide on yourself.

If someone has been working with pesticides and you see any possible symptoms of pesticide poisoning or injury, take emergency action immediately.

IF AN ACCIDENT OR POISONING HAPPENS

- Protect yourself from injury first.
- Stop the exposure to the pesticide. Move the victim away from the contaminated area.
- Check the four basic facts — identify the pesticide, the quantity, the route of entry and time of exposure.
- Call an ambulance or the Poison Information Centre.
- Start first aid. This is not a substitute for professional medical help.
- **Provide the label, MSDS sheet or container to emergency personnel** at the scene — or take it with you to the hospital. Do not transport pesticide containers in the passenger compartment of the vehicle.

FIRST AID

If a pesticide comes in contact with skin:

- remove all contaminated clothing; wash skin thoroughly with lots of soap and warm water
- dry skin well and cover with clean clothing or other clean material.

If pesticide comes in contact with eyes:

- hold eyelids open; wash the eyes with clean running water for 15 minutes or more.

If pesticide was inhaled:

- move the victim to fresh air and loosen tight clothing
- give artificial respiration if the victim is not breathing.

Do not breathe in the exhaled air from the victim — you could also be poisoned.

If a pesticide was swallowed:

- call the Poison Information Centre **IMMEDIATELY.**

Emergency numbers are listed at the front of each Bell telephone directory.

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